METAL PROGRESS

NOVEMBER 1931

A Million Small Parts Were Headed for the Scrap Pile

NOT long ago a manufacturer well known in the automotive field had more than a million semi-finished steel parts which had been discarded because of surface de-carburization due to improper cooling.

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METAL PROGRESS

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Ernest E. Thum, Editor.

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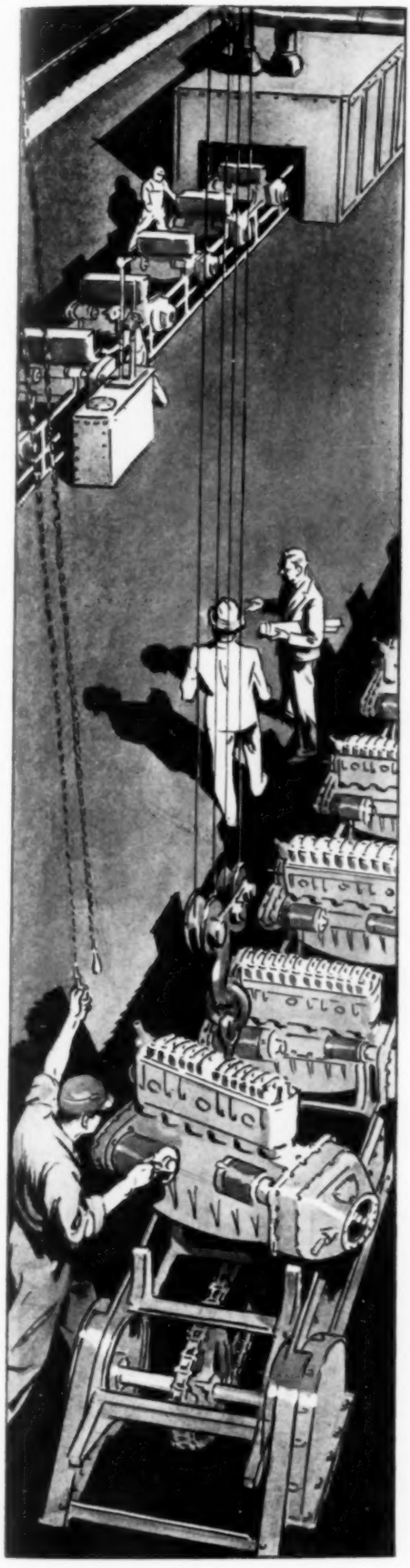

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T. J. Skillman

William Campbell

Robert G. Guthrie

John H. Hall

Arne Westgren

In This Issue

Differences between the rails of 1931 and those of 1831 are described by THOMAS J. SKILLMAN, chief engineer of the Pennsylvania Railroad, in the article beginning on page 37. Mr. Skillman graduated from Princeton in 1898, served nine months in the Spanish-American War in Porto Rico, and at the age of 23 was employed by the Pennsylvania Railroad as blueprint boy in the office of the division engineer. He advanced rapidly, and was made chief engineer in 1927.

Gas carburizing is described on page 50 by ROBERT G. GUTHRIE, president of the A.S.S.T. in 1930, and now a member of the board of directors. Mr. Guthrie is chief metallurgist for the Peoples' Gas Light & Coke Co. His fame as a metallographist is international.

WILLIAM CAMPBELL, who, together with E. E. THUM, editor of METAL PROGRESS, wrote the article on ancient Greek iron which begins on page 43, was born and educated in England. In 1902, however, he came to this country to study at Columbia University, although his English training had earned for him the degree of Sc.D. In 1903 he received the degree of Ph.D. from Columbia. At present he is professor in that university's School of Mines. His American professional career has included the positions of metallographist at the U.S. Bureau of Mines and lecturer on metallurgy at the U.S. Naval Academy post-graduate school.

Another article in the series which DR. ARNE WESTGREN has prepared for METAL PROGRESS begins on page 57. Dr. Westgren is professor of general and inorganic chemistry at the University of Stockholm in Sweden.

JOHN HOWE HALL, nephew of the late Dr. Henry Marion Howe, dean of American steel metallurgists, has become renowned in his own name for his work as technical assistant to the president of Taylor-Wharton Iron and Steel Corp., with which company he has been associated, with the exception of one year, since 1911. Mr. Howe has prepared an article on manganese-nickel steel, starting on page 69.

The story on page 55 on centrifugal spinning of bearings was written by the assistant metallurgist of the White Motor Co., ROBERT E. BULTMAN, who has been associated with that company since 1923.

The photograph used on the cover of this issue was taken by JOHN P. MUDD, mechanical engineer for the Midvale Co. Mr. Mudd's industrial photographs have been accepted for exhibition in many of the photographic salons in America and Europe.

RIEHLE is awake ..*wide awake!*

AT THE Riehle booth at the National Metal Congress in September, one of a group of three turned to his associates — they were looking at the new Riehle Precision Hydraulic Universal Testing Machine — and remarked (with some emphasis), "Well! They're awake at last, aren't they!" • The answer is, "Yes! Riehle is awake at last — wide awake. And has been for some little while." • This answer could not have been made two years ago — for then Riehle was known as (and justly so) one of those "good old-fashioned houses" — a good house to do business with, honest and sincere in every respect, but still "a good old-fashioned house," with all the phrase implies. • Riehle is still old fashioned in its belief that honesty and sincerity of purpose are the first requisites to a successful business. But in every other respect Riehle has "gone modern." As evidence of this statement we submit — first, the new Riehle Catalog — the most complete catalog in the physical testing field. (If you haven't a copy you can secure one simply by asking for it.) Then there's the new Riehle Precision Hydraulic Universal Testing Machine with Mercury Float Weighing Unit. (A new booklet on this machine is in preparation. If you'd like us to reserve a copy for you, write for it.) And the new Riehle Production Brinell Machine is almost ready for the market, as is the new Riehle Pendulum Type Torsion Machine. (Literature on these will be prepared soon, and, of course, we'll reserve it for you if you'll let us know you want it.) • These are but the visible evidences of new management within the Riehle organization — many other steps have been taken to insure you the fullest possible service. • Yes, gentlemen, Riehle is awake — wide awake! Only by so being can we be of fullest service to you and earn that approbation and confidence which will make you wish to do business with us.

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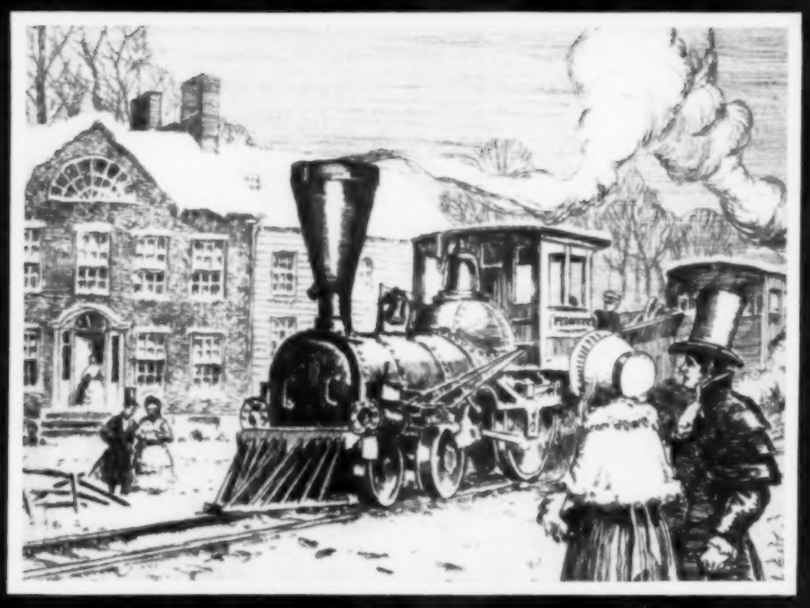


Then

and

Now

Otto Kuhler's etching of days gone by contrasts with the flashlight of the Broadway Limited, taking water on the fly at midnight. Photograph copyright by P. L. Mahaffey.

1831 — RAILS — 1931

a century of development

by T. J. Skillman
Chief Engineer
The Pennsylvania Railroad
Philadelphia

ON MAY 16, 1831, there arrived in Philadelphia the first T-rails ever produced. They were of rolled iron and weighed 36 lb. per yard. Just a century later, the first heats of a 152-lb. section were rolled of carbon steel and placed in our track. Further interest attaches to the fact that the original T-rail was designed for use on what is now a portion of the Pennsylvania Railroad System.

The pioneer Camden & South Amboy Railroad was organized in 1830 by some forward-looking citizens who saw the possibilities of a quicker and more convenient means of transport between Philadelphia and New York than the stagecoach or the canal boat. Passengers and freight were to be carried up the Delaware River to Bordentown, near Trenton, thence by rail 35 miles across the state to South Amboy on Raritan Bay, where another transfer was made to boats moving up the sheltered harbor waters to New York.

Minutes of the board of directors of the Camden & South Amboy Railroad show that in September, 1830, the president of the company, Robert L. Stevens, was instructed to visit England to inspect and report upon railroad matters there, and to make purchases of "all iron rail." Wooden rail, plated with strap iron, was used in the construction of many of the other early American roads, and was reasonably satisfactory where horses were used to draw the cars, but was inadequate for a locomotive.

Stevens sailed for England, and during the voyage he employed his time by whittling out model sections of all-iron rail from wood obtained from the ship's carpenter. His final conception was a practical model of the rail which, with slight variations in shape and increase in size and weight, is the standard used on all American railroads today.

The best railways of England at that time were being laid with what was known as the Birkenshaw rail, sometimes, from its shape, called the "fish belly." It had a head not unlike that of our T-rail, and a high web, but it had no base.

Birkenshaw rail gave good results as far as operation of locomotives and cars was concerned, but it was expensive to lay, because its contour required that the baseless web should rest in cast iron chairs which, in turn, were spiked to stone blocks set at 3-ft. intervals.

Stevens perceived that this rail was not adapted to conditions in new America where metal workers were scarce and iron dear. He therefore conceived the idea of adding the continuous flat base, which dispensed with the necessity for chairs.

He also designed the "hook-headed" spike, which is substantially the railroad spike of today. The spikes were driven into wooden plugs inserted into the stone foundation blocks. To join the rail lengths together he rested the ends on wrought iron plates and devised what was called the "iron tongue," which later evolved into the fish plate and subsequently into the modern joint-bar. In the rail joint, as planned by Stevens, rivets were used; these have long since been replaced by the bolt and lock nut.

Upon arrival in London, Stevens addressed a letter to the ironmasters of Great Britain requesting bids. The letter read:

"At what rate will you contract to deliver at Liverpool, say from 500 to 600 tons of railway, of the best quality iron rolled to the above pattern in 12 or 16 feet lengths, to lap as shown in the drawing, with one hole at each end, and the projections on the lower flange at every 2 feet, cash on delivery?

"How soon could you make the first delivery, and at what rate per month until the whole is complete? Should the terms suit and the work give satisfaction a more extended order is likely to follow, as this is but about one-sixth part of the quantity required. Please to address your answer (as soon as convenient) to the care of Francis B. Ogden, consul of the United States at Liverpool."

He encountered great difficulties in inducing a British mill to attempt making rails of his design, and at first received no favorable replies to his proposals. All ironmasters, for various reasons, regarded his undertaking "as dangerous, or at least highly imprudent, and likely to prove disastrous to all concerned."

Stevens was, however, fortunate in being personally acquainted with John Guest, head of the firm of Guest, Lewis & Co., owners of the Dowlais Iron Works in Wales, and he prevailed upon Guest to have the rails rolled at his plant. The two journeyed to the works, where Stevens gave his personal supervision to the construction of the required rolls. After their completion, the firm gravely hesitated to use them for fear of damage to the mill. Upon learning of this, Stevens deposited a liberal sum to guarantee the cost of the repairs, if any should be required.

In point of fact, the rolling apparatus did break down several times. The first experimental rails came from the rolls "curled like snakes, and distorted in every imaginable way." At last, however, the mill men acquired the art of straightening the rail while it cooled.

A first shipment reached Philadelphia May 16, 1831, and consisted of 550 bars, each 18 ft. in length, and weighed 36 lb. to the yard.

In the second shipment the weight was increased to 42 lb. Over 30 miles of these rails was immediately laid on the line of the Camden & South Amboy, constituting the forerunner of modern railroad track construction not only for the United States but for the world at large.

A piece of this original track still lies alongside the Pennsylvania line about 20 miles northeast of Trenton, New Jersey. Despite the fact that it has been exposed to the elements for a

A Century of Rail Development in America. Scale, one-third size

1931 Rail and Roadbed is in High Contrast With the Century-Old Relic Photographed on Page 42

full century, this old relic of the infancy of America's railway system is in a fair state of preservation and gives promise of lasting still another hundred years. It was laid on great stone blocks 2 ft. square bought from the prison authorities at Sing Sing, N. Y.

It is interesting to note that in building this early railroad into South Amboy, iron rails were spiked directly to wooden crossties for the first time in railroad history. Authorities at Sing Sing having failed to deliver stone blocks rapidly enough, the engineers in charge ordered hewn wood crossties to be laid temporarily, the rail to be spiked directly to the ties. To the astonishment of all they gave such satisfactory service and were so ideally suited to the purpose that they were permitted to remain.

From Stevens' T-rail of 1831 to the 152-lb. section of 1931 is a far cry, and many steps have intervened. It is necessary, however, to pass them by with a brief reference to the adoption of steel rail, and a photograph showing some of the standard sections representing "the last word" of various decades. It may be appropriate to make reference to the fact that the Pennsylvania Railroad was the first American system to adopt steel rails.

In 1862, John Edgar Thomson, then president of the Pennsylvania Railroad, made a study of the production of bessemer steel rails in England, and purchased 400 tons for experimental use. The weight of these rails was 56 lb. to the yard. They were placed in the track between Altoona and Pittsburgh, and the results were so favorable that the management decided to adopt steel rails as standard.

Other railroads rapidly followed suit. Within ten years considerable information about the performance of the new rails was available, and the American Society of Civil Engineers appointed a committee to report on forms, sizes, manufacture, tests, endurance, breaking, and comparative economy. *Transactions* of that society from 1874 to 1876 contain much information on this interesting transition. Space permits only one quotation: "A steel rail wears out; an iron rail is knocked to pieces before it is worn out. Our rails do not give out from want of strength, but from injury to head, not always perceptible to the eye." It was considered, therefore, that bessemer steel rail settled the problem of strength, having so much greater limit of elasticity than the iron rail. How the bessemer rail has been superseded by the low-phosphorus open-hearth rail in more recent years is a matter of common knowledge.

Railroading has continually developed toward increased capacity and lading for freight cars, increased weight of passenger equipment, increased length of trains in both branches of the service, and steadily advancing speeds. The influence of these factors on the size of rail in use is well shown by the photograph on page 40, and is likely to grow rather than diminish in the future. Where they are encountered in maximum degree, the result has already been the de-

First Steel Rail of 1866 Weighed 57 Lb. per Yard; 130-Lb. Section Has Been Main-Line Standard on Pennsylvania Railroad Since 1916. A much stiffer section, weighing only slightly more (131 lb.) is shown at the extreme right, and is small brother of the 152-lb. section for heaviest and fastest traffic. Scale, one-quarter size

velopment of wheel load pressures and the attainment of speeds beyond the ability of the rail heretofore in use to withstand. Indications that such a condition has been reached are given by the life of the present rail (a 130-lb. section adopted in 1916), the number of failures, and the annual expenditures required to maintain smooth-riding track, as well as evidences of deficiencies in splicing.

The problems of producing a stronger track with smoother and more comfortable riding qualities, capable of carrying safely increased traffic, with increased wheel load pressures, at increased speeds, and at the same time with more economical maintenance was studied by a group of executives, engineers and metallurgists of the U. S. Steel Corp. and various officials of the Pennsylvania Railroad system. They organized themselves into subcommittees on rail design, on joint design, on material quality and treatment, and on specifications.

These committees made thorough reviews and analyses of the problem, and set for their aim a rail design that would accommodate safely and satisfactorily 100,000-lb. axle loads at a speed of 100 miles per hour. These requirements compare with 80,000-lb. axle loads at speeds of 80 miles per hour, applicable to the 130-lb. main line standard rail section heretofore in use. It was concluded that this increased allowance for axle loads and speed would take care of the transportation developments of the next 25 years.

One of the important items to decide was the desired chemical composition of the steel. As late as 1926 the A.R.E.A. rail committee had revised its specifications and provided carbon limits of 0.72 to 0.89% for heavy rail. In order to keep closely in line with these recommendations we adopted the same limits for the Pennsylvania Railroad's specifications as of 1926. In this new problem we took cognizance of the fact that 0.85% carbon is considered to be the limit at which free or excess ferrite disappears. If the carbon should be carried too high, it exists as excess cementite, which is brittle.

At the same time we have been willing to replace some of this carbon with a somewhat higher allowance of manganese on account of the good effect of manganese other than its hardening quality, and especially because it acts well in heat treating. Our specifications were therefore revised accordingly by lowering the carbon and raising the manganese ranges.

Elements	Old Specification	New Specification
Carbon	0.72 to 0.89%	0.70 to 0.85%
Phosphorus	0.04 or under	0.04 or under
Manganese	0.50 to 0.90	0.70 to 1.00
Silicon	0.15 or over	0.15 to 0.30

Calculations of the stresses demonstrated

the necessity for a rail section in which would be incorporated, among others, the following features:

1. A height of approximately 8 in. (1⅜ in. higher than the 130-lb. section heretofore standard) as an important element in increasing the stiffness of the rail.

2. A head designed with as flat a radius as would be practicable to manufacture, in order to give broad contact with the wheel tread.

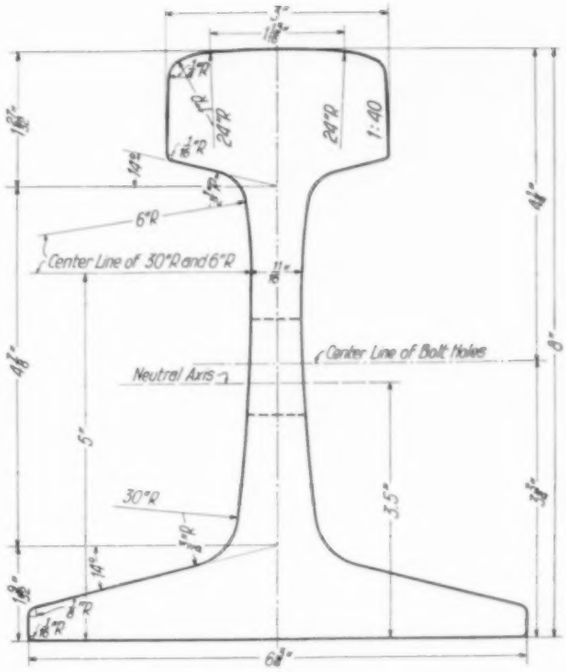
3. A definite desirable ratio of the perimeter of each portion of the rail (the head, the web, and the base) to their respective volumes, in order that the rate of cooling should be as nearly even as possible to minimize the setting up of internal stresses in the process.

4. That the rail should be canted in the ratio of 1 to 40, by use of a canted tie plate, as a further means of providing better contact between the head of the rail and the wheel tread. Side of head is also tapered 1:40.

Working out these requirements produced a section weighing 152 lb. to the yard and possessing 75% greater stiffness than the 130-lb. standard of 1916. As a result of the knowledge gained, the latter has also been revised to a 131-lb. section which will hereafter be the standard on main line track except under extraordinary conditions of traffic. The photographs of rail ends on page 40 show how the new 131-lb. section has a less bulky head and base, but a taller web. Principal data on the three designs are tabulated below; a dimensioned drawing of the 152-lb. section is also presented.

In order to minimize the stresses on the surface of the head, the wheel tread contours on many cars in active service were studied and an average made. As a result, it was found that a 24-in. radius for the surface of the rail head would be the nearest fit to the average contour that would be practicable to roll. Behavior of this rail in track has indicated that the contact between rail and wheel has been materially extended and the object sought has therefore been attained.

	130-lb. Section	131-lb. Section	152-lb. Section
Height of rail	6 5/16 in.	7 1/16 in.	8 in.
Width of head	3 in.	3 in.	3 in.
Radius of top surface	12 in.	24 in.	24 in.
Width of base	5 1/2 in.	6 in.	6 3/4 in.
Distribution of metal			
In head	39 %	35 %	32 %
In web	22 %	27 %	29 %
In base	39 %	38 %	39 %
Area of cross section	12.7 sq.in.	12.9 sq.in.	14.9 sq.in.
Moment of inertia	72.8 in.⁴	89 in.⁴	130 in.⁴
Ratio, moment to area	5.73	7.0	9.0
Neutral axis, above base	3.09 in.	3.2 in.	3.5 in.



152-Lb. Standard of 1930; Pennsylvania Railroad

Deficiencies in splicing were met by utilizing the greater fishing space provided in the higher web of the new rails. A simpler but more effective form of splice gives a much stiffer rail joint against vertical loads as well as lateral resiliency. The latter makes it possible to take up the wear between the under side of the rail head and the top of the splice.

During the summer two rollings (111 heats) were made at the Steelton plant of Bethlehem Steel Co. and two rollings (59 heats) at the Edgar Thomson works, Carnegie Steel Co. Specifications for manufacture were the same as established in 1926, except for chemistry and drop testing.

Mill practice in the two plants was, of course, not identical. All ingots were cast big end down. Bethlehem's ingots were 20x24 in. for three rails, and 25x30 in. for five rails; Carnegie's were 25x25 in. for four 39-ft. rails. Average discard at Steelton was 5.4% from bottom and 13.6% from top; 38 passes were re-

quired from ingot to rail. At Edgar Thomson works 3.5% was discarded from bottom, 15% from top, and 21 passes finished the rail.

Ingot temperatures taken after the first pass in the 48-in. blooming mill ranged from 1,995 to 2,130° F. Bloom temperature taken after first pass in roughing rolls (No. 2 rail mill) had dropped to the range 2,020 to 2,150°. Rail temperatures taken after the finishing pass were 1,810 to 1,900° F.

Quotations from the specifications will describe the care of rails after finishing:

"Care must be taken in cambering the rails and with the hot bed work so that rails will cool with a small but uniform sweep, and thereby gagging under the presses will be reduced to a minimum. When placed head up on a horizontal surface, rails that are slightly higher at the ends than the middle must have the same sweep uniform so that the middle ordinate does not exceed 1½ in. in 45 ft. or 1¼ in. in 39 ft. Rails while on the cooling beds shall be protected from snow, water, and excessive gusts of wind.

"The supports for rails in the straightening presses shall have flat surfaces and be free from hollow places, bends, or crooks, and shall be placed not less than 60 in.

"Rails heard to snap while being straightened shall be at once rejected."

Test pieces were cut from the crop of the top rail of the ingot; second, middle, and last full ingot of each heat was selected. Number of drop tests per heat ranged from 6 to 12. Standard A.R.E.A. tup and anvil were used; the distance between supports was fixed at 52 in. for the 152-lb. rail, and the 2,000-lb. tup was dropped 22 ft. each blow. It is thought that some improvements can be made in this practice and possible revisions are now under consideration.

From the four rollings above mentioned a total of 15,570 rails was produced. Of these, 13,452 were accepted as No. 1 rails, 968 were accepted as No. 2 rails, 811 were rejected for deficient ductility and breaking, 43 were rejected for surface defects, and 296 for pipe.

First rails were placed in eastbound track about 20 miles east of Horse Shoe Curve. This carries all the high speed passenger mail and express trains between Chicago and St. Louis and the eastern seaboard, and also all through freight. The tracks between New York and Washington which are now being electrified will eventually have 152-lb. rails to carry electric locomotives and passenger trains at speeds up to 90 miles an hour.

On account of the great weight of the rail (about a ton each), it is handled by crane from a track-laying train. Much labor-saving equipment is also furnished to the crew of 64 men, such as pneumatic spike pullers and drivers, gasoline-driven adzing machines for ties and grinding machines for rail joints.

ANCIENT GREEK IRON

was

sometimes steel

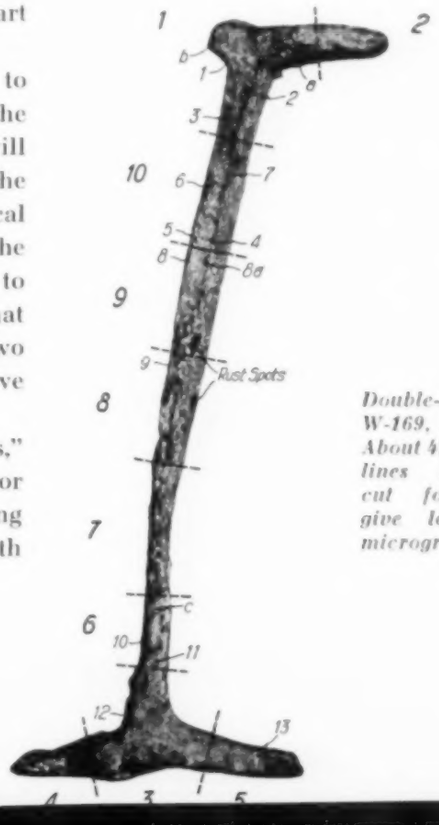
by William Campbell
Howe Professor of Metallurgy
Columbia University, New York
and Ernest E. Thum

STUDIES into the origin of any art are peculiarly fascinating. Most of the things which are fundamental to civilized life were discovered long before history began — planting and irrigating, spinning and weaving, and the domestication of animals. Manufacture of tools from metal, especially iron and steel, was a relatively late invention, but it was early enough so that even the place where the first iron originated is unknown, and the methods used in its making can only be inferred by some things which were recorded about the art centuries later.

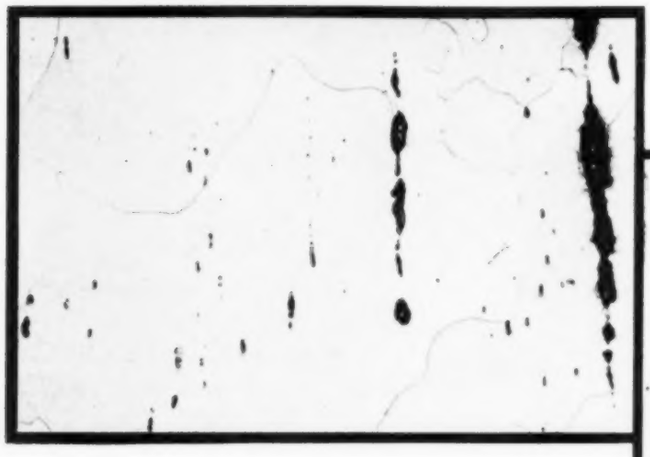
One method of solving the mystery is to look into the composition and structure of the ancient relics. Metallographic examination will indicate broadly the smelting method and the working and heat treatment. Precise chemical analysis, especially of the inclusions and the minor impurities, might even be expected to locate the ultimate origin of the ore. For that reason, some studies made early in 1930 on two Athenian relics nearly 2,400 years old have unusual interest.

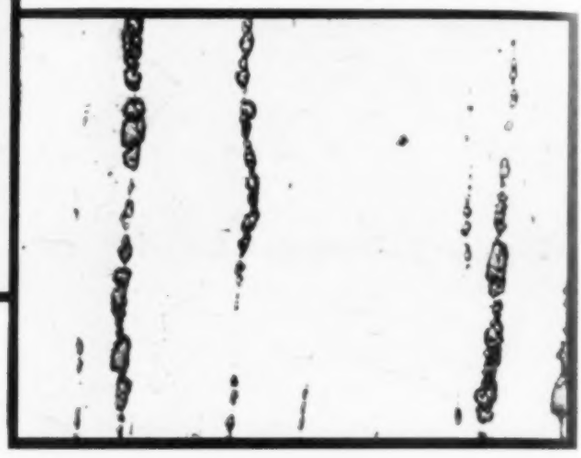
The specimens are "bonding clamps," secured from William B. Dinsmoor, professor of architecture, Columbia University. Bonding clamps were used in classical times by both Greeks and Romans to fasten together the adjoining blocks of a masonry wall laid up "dry" — that is, without mortar or cement.

Architecture of early Greece is famed for its classic Doric and Ionic columns, for buildings made of large blocks of smoothly polished stone and marble. Small use was made of metal in the period when Athenian architecture and sculpture reached their highest stage of development; iron at that time was a semi-precious



Double-T Iron Clamp, W-169, Made by Athenians About 425 B.C. Dotted cross lines represent sections cut for study; figures give location of photomicrographs. Scale ½ size





W-169 at 8, at Left, With Enormous Ferrite Grains, Is Evidence That Cold Worked Portion Was Reheated at Dull Red Heat for Some Time. W-169 at 3, shown below, with shattered slag stringers indicates a low working temperature

metal used in inlays. But somewhat later, with the beginning of the period that built such famed structures as the Acropolis at Athens and the Parthenon, iron became a utilitarian metal — not only for tools and weapons but also for structural purposes.

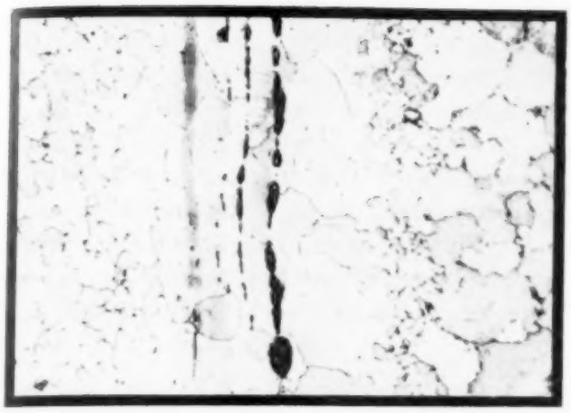
Lime-mortar or any other kind of manufactured cement was unknown to Grecian builders, although it was used prior to that time in Mesopotamia and Egypt and contemporaneously in Roman areas. Sometimes blocks of stone were quarried which were large enough to form an entire part of a design without any joining; more often some sort of bonding method other than cement was necessary. For this purpose the Greeks devised a system of iron clamps and dowels which held the blocks firmly together and protected them against separation by earthquakes or other causes. According to Prof. Dinsmoor, the material was usually forged iron except in structures exposed to water and dampness where bronze was sometimes substituted.

It is interesting to note in passing that the Balkan peoples even today are skilled in the art of building dry walls, and any gang of Montenegrin, Serbian, or Albanian laborers will be sure to include masons capable of doing remarkable work of this sort.

These horizontal clamps were used by their ancestors to join blocks in the same course; upright dowels served to hold together upper and lower blocks and prevent them from slipping. Much of our information regarding the shapes and forms of these pieces is obtained from the cuttings in the stones, since the metal has vanished.

Clamps were in use earlier than dowels and variations in thickness of the bar or design of the heads (or ends) permit archeologists to date them fairly accurately. The earliest type was a horizontal bar with ends bent at right angles either in the form of a Z or with both ends bent in the same direction. Double-T or H types, such as the ones now under examination, are commonest and were used in the best construction in Athens between 520 and 320 B.C. It is also a horizontal bar and the cuttings on either side of the stone joint, as seen from above, resemble the letter T. It is also the most complicated type, since the cross ends could not

W-169 at 2 Shows Stringer of Low Carbon Steel Starting in Upper Flange Reappearing Frequently at Edge of Web and Redeveloped in Lower Flange



W-169 at 4 Is Another View of the Steel Stringer, Where the Combination of Forging and Reheating Has Been Insufficient to Refine the Grain Completely. A "ghost" parallels the slag stringers

have been formed by simple bending. Another style of clamp had the ends bent at right angles vertically, while still another was of "swallow-tail" shape, wide at the ends and narrow at the stone joint.

In a wall of normal thickness two clamps were used across each joint. They varied from 3 in. to nearly 3 ft. in length, depending upon their position. The longest known clamp cutting is in the northwest capital of the Propylæa (gateway to the Acropolis). It is a double T 31.5 in. long, 0.7 in. wide, 6 in. across the head, and 4.3 in. deep. The clamps were laid in cavities or cuttings of the same shape but slightly larger than the iron in all directions. The cavities were then filled with molten lead, tamped down with a pointed tool as it cooled. The lead packing not only made the clamp fit more tightly, but also protected it from oxidation.

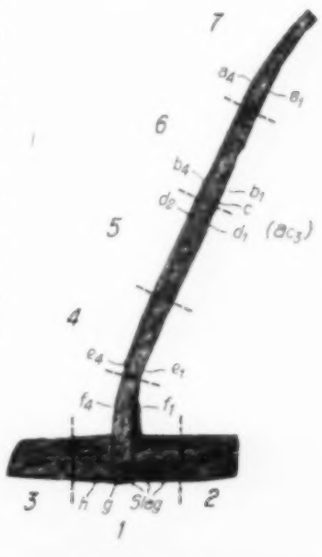
Dowels were upright iron bars, sometimes round but usually square in cross-section and of various ingenious shapes. They were about 3 in. long, 1 in. wide, and 2 in. deep in both upper and lower stones. As a preliminary operation, the dowel was usually leaded into the cavity provided in the upper stone, which was then turned over and set in place so that the projecting end of the dowel fitted into the cavity in the lower block. Molten lead was finally poured through a horizontal channel cut into the upper surface of this block to seal the lower end of the dowel. Channels were also oblique and vertical, depending upon the shape of the blocks and the location of the joint.

A somewhat similar device was the wooden or bronze pivot joining the centers of drums or sections of columns. These drums could then be rotated about the pivot until a nearly perfect joint was secured.

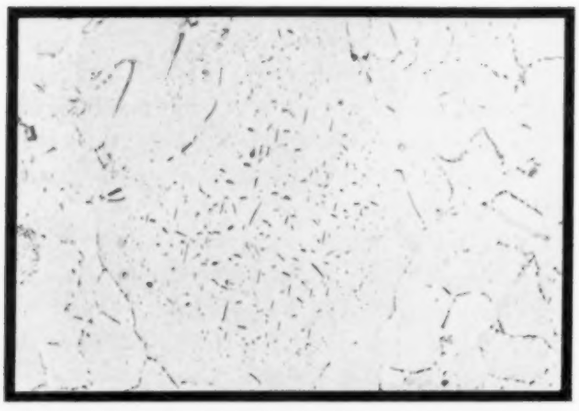
Let us first consider the more perfect piece, known as W-169. It is of an average size for such bonding clamps, being about 9 in. long, and is complete except for the loss of part of one flange. It was found on the Acropolis in Athens in debris heaped up by the Turks about 1690 A.D., and so probably belonged to one of the 2,000-year old structures built about 450 to 400 B.C. which the Turks were demolishing for the sake of building material.

There was a good deal of adherent rust on the surface, especially near 1, where the flange joins the web. This is made up of three oxides very markedly differing in color and hardness. One constituent is very much darker than the others and occurs in irregular grains. At a few places the slag enclosures near the surface marked the location of bands of oxide. The sketch also shows two curious rust pits on section No. 8 with at least three different oxides, somewhat resembling those near the flanges.

In general, the metal in the upper portion (pieces 1 to 7) resembles ordinary wrought iron as regards the amount of slag, appearance of the ferrite crystals, and absence of pearlite. W-169 at 3 is representative. The metal has evidently been worked at a comparatively low temperature, as shown by the shattering of the slag stringers. Distorted metallic grains near the surface at two points where web joins flange indicate cold work, but this may be of recent occurrence.



Steel Clamp, W-170, Made 2,365 Years Ago, Installed in the Gateway of the Acropolis, and Broken in the Seventeenth Century



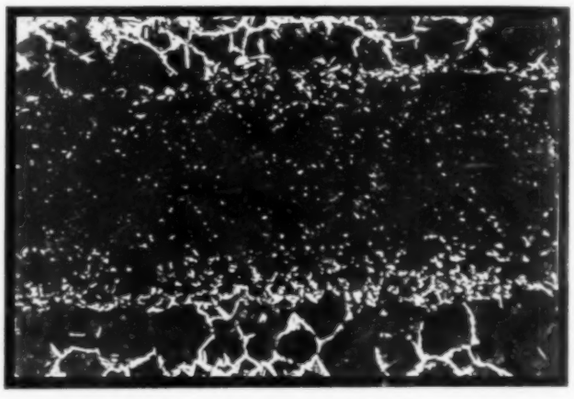
W-169 at 11 (250 Diameters) Shows That Nitride Needles Formed in Low Carbon Steel Made in an Athenian Forge, Just as in Modern Electric Welds

Slags are duplex in structure, showing lighter grains in a darker matrix, similar to puddled or charcoal hearth iron slag.

The ferrite grain of medium size shown in the above-mentioned micro becomes larger and larger in size toward the center of the web. At 6 the average grain size is more than doubled and in W-169 at 8 they become enormous. This coarsening of the ferrite is associated with the phenomenon of "Stead's brittleness," and is caused by a small but critical amount of cold work, followed by heating to a correct recrystallization temperature — approximately dull red heat for ferrite. Mixtures of very fine and very coarse grains (due to the same cause but when sufficient time has not been given for the large grains to swallow all their small neighbors) exist throughout the web — down as far as position 10.

There is a band of low-carbon steel (W-169 at 2) beginning in the upper flange and continuing down into the web. A band or strip of very low carbon steel reappears at various places on the right surface of the web, such as at 7, and W-169 at 4. Here the low-carbon zone at the very surface (right edge) is coarse-grained. The most of this section is a mixture of coarse and fine-grained ferrite such as would be produced by heating the metal just to recrystallizing temperature but not long enough for the change to become complete. In other words, the metal is partially refined at this side. Parallel to the slag stringers shown in the micro is a thin dark-etching band, usually called a ghost, due to segregation of phosphorus. There is much less slag included in the steel (metal which is definitely carburized) than in the wrought iron (carbon-free ferrite).

Within these large grains near the slag streak (W-169 at 4) may also be seen some markings which become more and more pronounced as the base of the clamp is approached. They seem to favor the right-hand edge, where there was apparently some low-carbon steel in the bloom which was forged into the original bar. For instance, the carbon-free iron grains at 8 are clear; at 8a they have cloudy centers. In piece No. 7 a pronounced area of slag and oxide runs down the center dividing and extending into No. 6. On the right the ferrite is clear; on the left the ferrite grains are full of tiny needles.



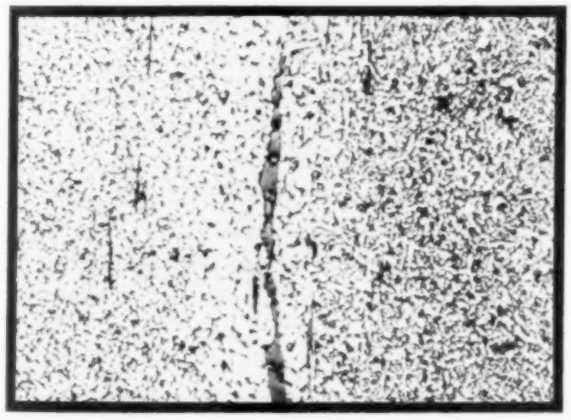
W-170 at b, Shows a Band of Pearlite in Which a Few Tiny Dots of White Ferrite Indicate That the Metal Has Been Heated to the Lower Critical Point, 1,375° F.

W-169 at 11, at higher magnification (250 diameters), shows the structure. Within the grains the foreign constituent looks like tiny needles and dots; the grain edges are relatively clear, but some inter-crystalline material marks the grain boundaries. One of these samples was submitted to George F. Comstock, an authority on inclusions, and he identified them as nitride, but was unable to give a reason for their presence. Our previous experience with nitride in iron and steel has been limited to electric welds and pieces of iron or low-carbon steel which had been nitrided. Comparing the data on weld metal published by Messrs. Hensel and

Larsen in September METAL PROGRESS, page 41, it would seem that this portion of the ancient iron clamp contains considerably less than an average arc weld (0.147% N_2). The nitride goes into solution in ferrite progressively up to about 1,100° F. Precipitation in visible needles seems to require tempering the solid solution at 200 to 400° F. A considerable stay at this temperature or even higher might permit the nitrides to migrate to the grain borders, leaving a relatively clear shell.

In the lower flange, the left-hand portion of No. 3 and all of No. 4 show clear ferrite and fractured slag stringers. At the right, however, and in part of No. 5, a marked band of low-carbon steel persists to the toe of the flange. The coarser ferrite grains also show nitride needles. In the low-carbon steel band the grain is extremely fine, resembling metal which has been heated to Ac_3.

From these observations it seems fair to conclude that the metal was made in some crude hearth where the smelting conditions were quite variable — in one place producing iron practically carbon free, and in another a low-carbon steel containing considerable nitrogen (perhaps some manure mixed with the ore was responsible for the latter). The original bar also was hammered some after it became fairly cold; heat drawn back from the ends when the clamp was being made caused excessive grain growth in the fragmented iron crystals. The lower flange was shaped first, by an upsetting process, the last heat being at about 1,400° F. (cherry red), which refined the grain of the steel streak. Work on the upper flange required several reheatings, or else the bar was carelessly left in the forge; heat working back toward the completed flange kept it at moderate temperature for quite a long time — sufficient to allow considerable migration of iron nitride crystals.



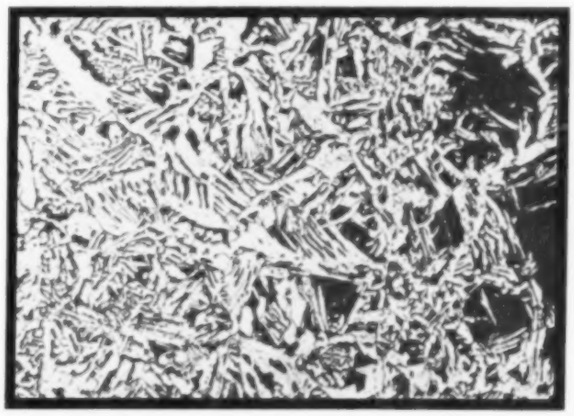
W-170 at d_5, With Exceedingly Fine Grain, Has Probably Been Heated to the Upper Critical, 1,650° F. Slag inclusions indicate that the metal was smelted from ore

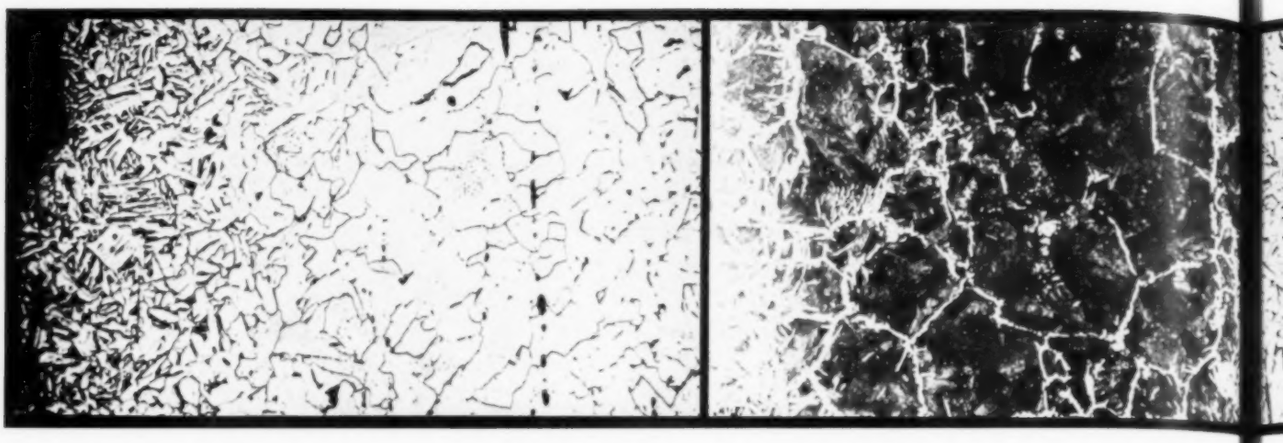
Specimen W-170, one of whose flanges is missing, can be dated more exactly than the other, for it comes from the gateway of the Acropolis, known to have been erected during the years 437 to 432 B.C. It is only a half-clamp, the shank having been pulled apart in tension — necked down and of irregular fracture. It may have been broken in 1645, when a violent explosion of war stores occurred, or during the bombardment of 1687. At any rate, the age of this piece is 2,365 years, and the one already described is just about the same.

In contrast to the other clamp, W-170 has very little slag in it; its microstructure is that of steel rather than wrought iron. The steel varies in carbon content from as low as 0.10% up to 0.90%; various bands of "raw steel" have different amounts of carbon, and on etching the metal is markedly banded to the eye. It resembles certain brands of Swedish charcoal hearth iron used nowadays in the manufacture of crucible steel.

Piece 7 has high carbon bands, appearing to run out at one side because the metal has evidently rusted away there and at the top end has been reduced to a narrow point by rusting

W-170 at e_1 Has Been Sadly Overheated





Structure Across W-170 From a_5 to a_1 Shows Relatively Little Slag. The metal consists of bands of steel of various carbon concentration, ranging from almost nothing up to eutectoid. Below is structure across W-170 from f_5 to f_1 which indicates that the piece was locally quenched, possibly by vise jaws while the flange was upset

and by elongation occurring during the fracture.

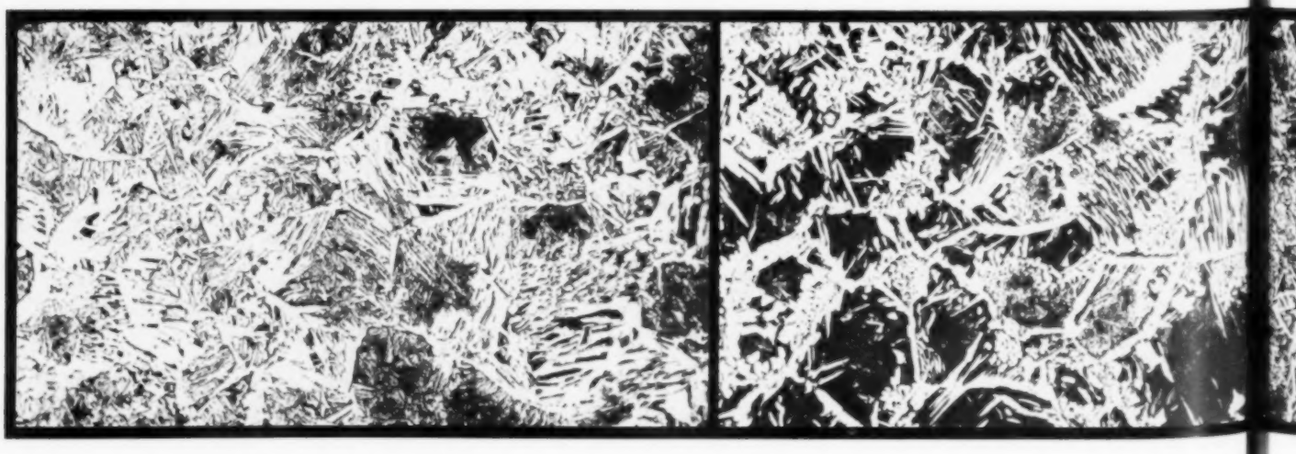
This structure is shown by the upper band of micros on these two pages, which together form a practically continuous picture of the metal from a_4 to a_1. On the left side is an outer surface of ferrite containing a small amount of pearlite. This soon disappears, leaving a zone of polygonal ferrite, in the center of which is a line of slag globulets. The next section toward the right contains a band of "raw steel" in the center — it is nearly all pearlite (0.85% carbon) with only a little ferrite at the grain boundaries.

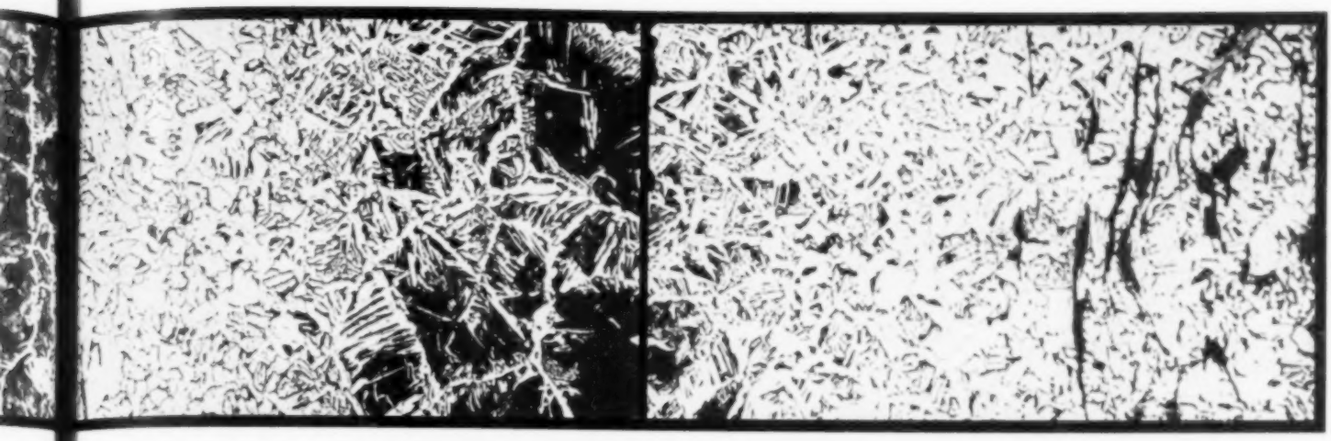
Down the center of the bar is a strip of low-carbon steel, passing through a band of comparatively high-carbon material. Then is a skin of comparatively low-carbon steel, at this place containing several irregular and elongated patches of slag.

Sections across the bar at other places show similar alternations of low-carbon and high-carbon bands. Sometimes the latter arrive at the surface.

At W-170 at b_4 there is, for instance, an outer skin of nearly pure ferrite which changes within a few thousandths of an inch to a thin band of dark pearlite with a few tiny dots of white ferrite. Such a structure in the last-mentioned band could be obtained by heating this metal to the lower critical point, say 1,375° F.

In the lower part of section 6 and the upper part of 5 the grain of the low-carbon steel is exceedingly fine (micro W-170 at d_1), resembling





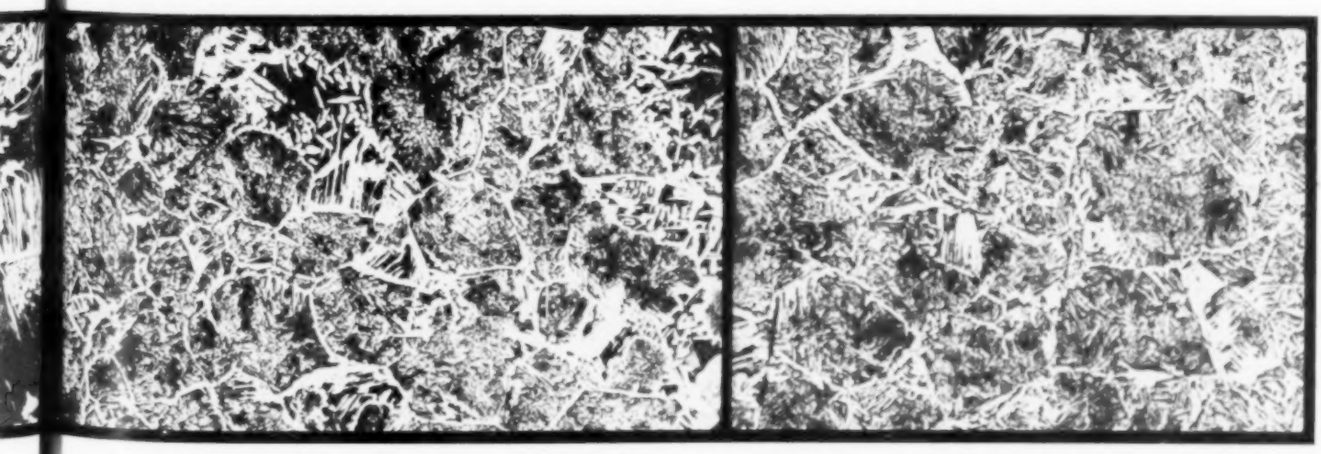
metal which has been heated to the upper critical point Ac_3 — say about 1,650° F. for such an analysis. Slag inclusions, although not large or numerous, indicate that this steel has never been melted, but smelted direct from the ore.

Grain size from here grows coarser toward the lower flange, reaching a maximum at e. W-170 at e_4 shows coarse overheated low-carbon metal at the left-hand surface, increasing in carbon at the right. Similar variations in the banding extend clear across the section to e_1. Such a coarsened structure is obtained by heating steel to a white heat and cooling in air.

Further toward the base, across section f_4 to f_1, the structure is peculiar enough to warrant a second band of micros, reproduced below. The left-hand view is one diameter (or about 0.04 in.) from the left surface, and consists of white ferrite of overheated structure and patches of brown troostite, passing into sorbite toward the right. Somewhat deeper (next view to right) the metal is higher carbon. Dark areas are sorbite. Peculiar rosettes appear within the lighter etching grains, a structure that is more pronounced as the field advances toward f_1. The last view, on page 94, at 500 diameters, shows one of the light etching areas; it contains little ferrite; it is called troostite for want of a better name, though it might even be called martensite.

The evidence is that the material near the neck was rapidly cooled from a white heat — possibly by gripping in a vise while the base was being upset. The structure is too localized to have been caused by quenching.

Two marked bands of raw steel turn toward the right flange of the base, and a third is acquired on its top surface as the lower one fades away. The central and left portions are generally of low-carbon steel (say about 0.10%) with fine grain, as though forged down to a low temperature. *(Continued on page 94)*



CARBURIZATION

of steel

with gas

by R. G. Guthrie
Peoples Gas Light & Coke Co.
Chicago

IN the latter part of 1926 a research was started in a well-equipped laboratory maintained by Peoples Gas Light & Coke Co., aiming to reveal, if possible, some of the fundamentals of the carburizing process. Since that time information and papers of popular as well as technical mien have been issued from this laboratory under authorship of Dr. O. J. Wilbor, J. A. Comstock, and the writer. Some patents have been secured as a result, notably one on the use of ordinary gases from a carburetted blue water gas and the various mixed gases as they are supplied today for city use, and another on the surge method of carburization, a development particularly adapted to the so-called heavy or heavier hydrocarbons, such as natural gas, propane, or butane.

These papers and patents contain many details regarding this more or less lengthy research, the main principles discovered, and enough of the results to enable those interested to carry on and form conclusions based upon our work.

In publishing this simplified synopsis, I hope that it will be received in the light in which it is given — as a progress report upon this research rather than the final and conclusive results, or a highly technical paper giving details of the processes investigated.

It is for that reason that it is given without detailed data or tabular results, and I trust that it will clarify in the reader's mind certain phases of this activity which will enable him to understand better the work that has been accomplished.

Inasmuch as the carburization of iron and steel consists of heating the metal (ordinarily of low carbon content, either with or without alloying elements), it becomes of paramount importance first, to secure uniformity of product, second, to control the various phases of the operation as closely as possible, and third, to accomplish all this in the cheapest way without sacrificing any of the quality.

In the earlier forms of carburizing, the material to be carburized is heated in company with a carbonaceous material, which will evolve a gas at the furnace temperatures. It is from this gas that the iron or steel absorbs sufficient carbon to raise its carbon content in the outer surfaces and thereby lend itself to the later treatment of hardening and tempering.

The carbonaceous material from which the gas is evolved was known as "compound" and still is. It consists of bone or various kinds of charcoal such as charred leather or coke, together with re-activators such as barium carbonate, sodium carbonate, magnesium carbonate, or ammonia compounds, there being as many different mixtures and types of re-activators as there are different types of compounds.

Liquid carburizers, such as cyanides, have also been used, in which considerable nitrogen is present. These produce a carbon-nitrogen case that is comparatively low in carbon, and generally extends to very superficial depths. Although such a case, after quenching, possesses high hardness, it is also possessed of considerable brittleness, and this limits the use of this process for case carburizing (although cyanide baths have definite values as heating mediums).

Oils and other liquids have been used as a source of carbon for case hardening at various times and still are, for that matter, but are usually accompanied by some re-activating material high in oxygen. Such compounds may be slowly dripped into some sort of circulating device within the box or retort and volatilized, thereby forming the gas necessary for carburization.

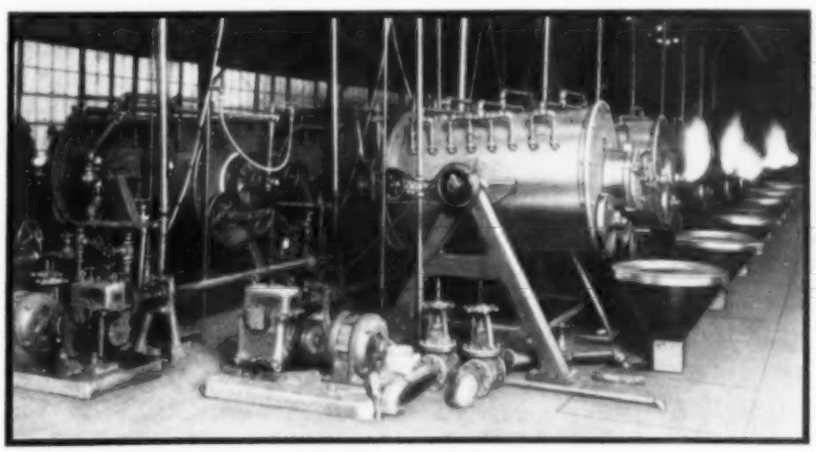
It is interesting to note that, irrespective of the type of carburizer used, its final form, before giving up carbon to the steel, is always gaseous. It would seem that if the most is to be obtained from a given carburizing agent, it should first be in the gaseous form before entering the retort, as the efficiency, uniformity, and quality of case are very closely allied and dependent upon the chemical equilibrium maintained by the carburizing agent and the hot parts to be carburized. We have found it to be impossible to secure constant conditions of equilibrium with any carburizers other than those originally in the gaseous form. Reactions during the evolution of gas from solid or liquid carburizers interfere materially with the maintenance of a comparable equilibrium between that carburizing agent and the iron and steel.

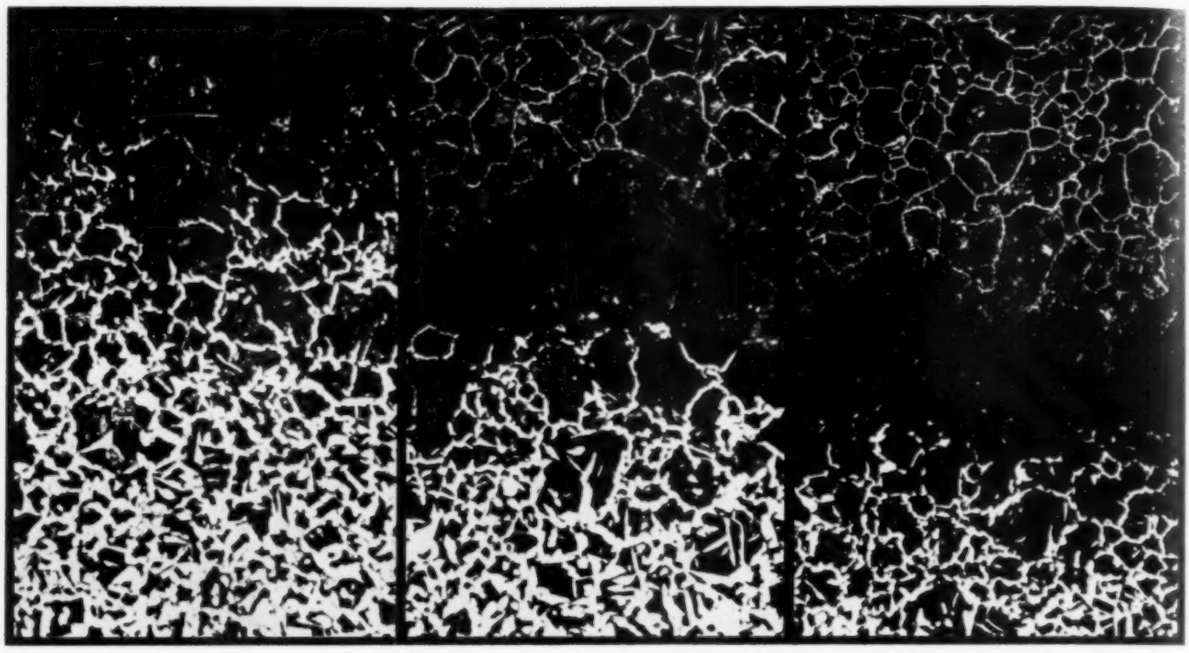
Another important fact about solid or liquid carburizers which we have found out is the fact that, within reasonable limits, the *concentration* of a given case is not dependent upon the *depth* of a given case. It is impossible to control this concentration per unit depth (for a given type of steel) unless the carburizing medium is in the gaseous state — thereupon this equilibrium may be maintained with great accuracy. It has become obvious that, where a carburizer is called upon to evolve gas in the presence of gas already evolved, and where the gas evolved is breaking down in the presence of the iron, a very complete set of reactions is under way, each one of which is very much dependent upon the others, and the entire set mitigating against any accurate control of either case concentration or case depth.

Reason for Selecting Gas

It was the realization of these facts, rather than the fact that we wished to promote the use of gas, that led us to select it as a carburizing medium. We have been amply repaid.

Our early experiences with a 550-B.t.u. mixed coke oven and carburetted blue water gas were disheartening from the standpoint of constancy of operation. At certain times excellent results could be obtained by merely introducing this so-called city gas into closed containers and proceeding with the carburizing, but frequently some unknown condition would arise





Widely Different Types of Cases Demanded Today in Production on 1020 S.A.E. Steel. At left is shallow eutectoid case; at center a shallow hyper-eutectoid case with eutectoid gradation zone; at left a strong hyper-eutectoid case with eutectoid gradation zone. Magnification 100 diameters

(not justifiable by any ordinary chemical analyses of the average gas atmosphere present) that would slow down the carburizing processes to one-half or one-third the normal.

For example: A given operation using 75 cu.ft. of gas per hr. at 15 lb. pressure would require 6 or 7 hr. to obtain a $\frac{1}{16}$-in. case, and without any apparent reason whatsoever would suddenly require 25 to 30 hr. to obtain the same case, if it was obtainable at all.

Without going into lengthy detail, I will consider it sufficient to say that the entire difficulty lay in the variable moisture content of such gas. We immediately took steps to dry it to a moisture content equivalent to saturation at 32° F., and this resulted in cutting down the amount of gas required for a given operation from 75 to 35 or 40 cu.ft.

It resulted in one more thing, however, that was very troublesome at first. That was a large precipitation of soot. Although the time of carburizing (to $\frac{1}{16}$-in. depth with a slightly hyper-eutectoid outer surface) was reduced, nevertheless, large masses of soot formed and messed up the operation. Inasmuch as the unsaturated hydrocarbons in this particular gas tend to break down at 1,275° F., while the carburizing process is carried on in the neighborhood of 1,700° F., it was obvious that the things so far gained were a reduction in gas consumption and constancy of operation. These, although very important, were not all the important things to be considered.

It was then discovered that if minute amounts of moisture were introduced into the hot retort at the beginning of the run, a peculiar condition was built up on various portions of the surface of the steel parts which would not in any way affect the parts themselves, but acted as a powerful inhibitor of reactions which precipitated soot in the latter stages of the run.

To state briefly the developments after this second discovery, it was found that when gas was used which was constantly saturated at approximately 32° F. with moisture, about 60 drops of water should be added at the very beginning of the run over a period of about 6 min. or more — in other words, at the rate of 10 drops per min. This amount of excess water is doubtless insufficient to form an inhibiting surface (a crystallized oxide or a chemical compound as shown in the micrograph on page 51) over the whole area of every piece in the carburizing box. This is unnecessary. It is doubt-

ful if this surface condition could ever be found except in isolated places, but its presence here and there prevents the deposition of excess soot when gas is flowing at a rate comparable to that necessary for successful carburization during periods as long as 25 hr. at temperatures between 1,700 and 1,800° F. Without the addition of this oxidizing agent in the gas at the beginning of the run, a volume of soot would be deposited equivalent to about one-third the volume of the carburizing container. The difference in the required time is, roughly, one hour in favor of the process mentioned.

Water Added at Start

This first process developed, therefore, consists of providing the carburizing furnaces with a drying medium, drying the gas introduced into the retorts at about 15 lb. per sq.in. pressure, and at the beginning of each run, when the steel is up to temperature, dropping 10 drops of water per min. for 6 min. into the retorts through a zero pressure regulator, thereafter shutting off the regulator and allowing the carburizing gas to flow through an ordinary 600-lb. retort at the rate of about 35 to 40 cu.ft. per hr.

This process very adequately takes care of gases of all types used for city gas up to and including the natural gases. However, as our researches continued, we found that the heavier hydrocarbons must be diluted to a mixture approximating the gas ordinarily supplied for city purposes — say, from 500 to 600 B.t.u. Otherwise, some other medium would have to be worked out which would allow these heavy hydrocarbons to be used without dilution.

Another observation was made at about this time which aided in solving the heavy hydrocarbon problem, and that is that a carburizing gas would not immediately purge itself from close proximity to the parts being carburized even if a considerable volume at high velocity was blown through the furnace. After the carburizing process started, a thin film of so-called dead gas seemed to adhere very tenaciously to the metal surfaces. We tried rapid circulation of these heavy hydrocarbons over the metal surface with a fair degree of success, but such a mechanical "scrubbing" of the surfaces to be carburized would not purge the adsorbed film sufficiently. Some chemical means must be found for removing this film, if carburizing with heavy hydrocarbons could ever be speeded to the point where it would be commercial.

Our second patent, on the surge method of carburizing, describes the solution of this problem. The process consists of using any of the heavy hydrocarbons in cycles, interposing an oxidizing gas between these cycles or surges of carburizing gas. Air, water vapor, CO_2, or any other form of oxidizing gas may be used which will not contribute any detrimental constituents to the metal.

Obviously, the simplest and most easily controlled medium to use for this purpose is CO_2. It introduces no danger from explosions, such as might readily result from the use of air. It must be understood that we do not mix this oxidizing gas with the hydrocarbon outside the retort, but merely introduce it in between the surges of the carburizing medium, when the supply valves for the latter are closed. The carburizing gas may be used in very small amounts; if used more generously, it may be recirculated two or three times before finally being exhausted from the system.

Intermittent Gas Supply

This second process, then, consists of surging a very dry, heavy hydrocarbon over the material to be carburized one or more times, depending upon its composition and the quantity used. It is done in the following manner: A given volume of hydrocarbon gas is put through the chamber and over the work at high pressure (7 to 15 lb.) in from 5 to 15 sec. and the gas valves closed for from 5 to 10 min. while the carburizing proceeds. This volume is again put over the material in much the same way, and this is repeated three times with a 5 to 10-min. stand-by (with no gas entering) between each surge; the number of times will depend upon the volume of gas and its composition. Then 5% of CO_2 is shot in in the same way for one cycle, which clears the retort of residual hydrocarbon gas and again re-activates the metal surfaces so they will be as receptive to the carbonaceous gas as they were at the very beginning of the process.

This oxidizing gas, with whatever hydro-

Microscopic View of Crystallized Sub-Oxide of Iron Necessary to Inhibit Soot Formation While Carburizing With Gas

carbon gas is remaining in the retort and on the surfaces of the steel, is free to exhaust into the atmosphere from the circulating system for a 5-min. interval, and then the surges of hydrocarbon gas again begin. The entire cycle is repeated over and over until the desired depth of case is obtained.

It might be said that as far as the efficiency of this process is concerned, it still takes about five hours to obtain a $\frac{1}{16}$-in. case at temperatures between 1,700 and 1,800° F., and the amount of carburizing gas will be directly proportional to the carbon concentration of such a gas. In other words, the richer and heavier the hydrocarbon, the less of it is necessary per surge, and consequently, the less is required per unit of time. The more diluted or lighter the concentration of available carbon in a given gas, the more of this gas will obviously be necessary per surge, and, consequently, the more of it will be necessary per unit of time to attain the desired results.

This process may seem complicated, but in plant operation a program clock arrangement is used, which takes care of these surges automatically. The process, therefore, becomes very simple and highly efficient. It allows considerable leeway in the control of carbon concentration in the case, and for this purpose various phases of equilibrium may be maintained by varying the amount and number of circulations of the oxidizing gas.

This latter consideration has to be worked out for each type of steel, as it does in the first process explained (where moisture in measured amounts may be continually added to the process and may thereby cut down the tendency to build up a hyper-eutectoid concentration at the outer surface).

Throughout both of these processes, it is extremely important that the moisture content of all gases used be under absolute control at all times. A variation in the moisture will result, within certain limits, in about the same depth of case, but in a considerably different carbon concentration in the outer edges. The hydrogen from the dissociated water affects the chemical equilibrium probably more than any other single element. Inasmuch as this equilibrium may be controlled, so may the concentration for various depths of case. (There are many other factors entering into the more technical considerations of the carburizing process which are much too lengthly and require far too much explanation to be dealt with in a paper such as this is intended to be.)

It has therefore been necessary to develop special instruments or mechanisms which may simply and efficiently check the moisture content of the gas issuing from the dryers, and to indicate throughout the carburizing run the equilibrium conditions within the retort. The latter was developed by Dr. O. J. Wilbor of the Peoples Gas Light & Coke Co.'s laboratory, and is of more than passing significance. It enables us to keep a very close check upon the equilibrium conditions within the retort and to proceed throughout any given portion of the operation or the operation as a whole, knowing just what is going on within the retort at all times and being able to control it.

BABBITT BEARINGS

spun and

diamond cut

by **Robert E. Bultman**
Assistant Metallurgist
White Motor Co.
Cleveland

ALTHOUGH ball bearings and roller bearings have been applied successfully to many motor-car and machine parts, babbitt and bronze bearings are still favored in many locations. It is not the intention to discuss the relative merits — merely to describe some methods whereby production may be increased and the bearings themselves bettered by the use of a simple machine for centrifugally spinning babbitt into connecting rods. The machine is simple, and variants of it have been in operation in many plants for a long time. However, the experience of White Motor Co., of Cleveland, manufacturer of heavy trucks and busses, has been so satisfactory that a brief outline of methods may encourage other men in the metal industry to take similar steps to improve their product.

The machine itself consists of a disk or face plate mounted on a horizontal revolving shaft. An old lathe head or grinding wheel is suitable. The disk carries a jig to hold the crankshaft end of the connecting rod in its exact center, and a sheet metal shield catches spatters of molten babbitt. (In the view, the shield door is in the open position.) A small center opening is left in the front of the shield for pouring the babbitt; for this purpose a hand ladle with long protruding lip is required.

Both halves of the bearing are fitted together in order to pour the complete bearing. Assembly is accomplished quickly with bolts and temporary shims made of thin cast iron which keep the babbitt from forming a continuous circle within the rod and cap.

Assembled rods are first dipped in a commercial muriatic acid flux and then in pure, virgin tin. During this time the steel comes nearly to the heat of the molten tin, 550° F., but it cools about 50° while surplus tin is being brushed away and while it is being placed into the fixture on the spinning machine.

Babbitt, meanwhile, has been waiting molten in adjacent pots, maintained at a constant temperature of 650° F. When the rod is locked in place the front shield is snapped shut, and the power turned on. As soon as the rod and disk are rotating at proper high speed (645 r.p.m.) the operator pours a measured amount of babbitt into position within the rod. Power is then shut off and when rotation has died away the metal has solidified and the rod can be removed.

Centrifugal force distributes the babbitt

evenly in the proper channel, quickly producing a close-packed, smooth bearing surface easy to finish and ideal in its properties to resist severe service. About 23 connecting rods can be assembled, tinned and babbitted on this machine in an hour by one man.

Remaining operations on the bearings are few and do not require much time. Very little surplus metal has to be removed because the centrifugal method of casting lays down a surface that is itself comparatively smooth, and the thickness of the bushing can be easily controlled by regulating the amount of babbitt poured for each bearing.

The bearing is rough machined and then finished with a diamond tool on a special boring machine at high speed. This finish is a matter no less essential to a high grade bearing than the dense uniform structure achieved by the method of casting.

If a babbitt bearing finished with an ordinary tool is examined under a microscope at 50 or 100 diameters the tool marks are plainly seen as tiny parallel ridges. Furthermore, very few of the white, shiny crystals of hard antimony-tin solid solution are left behind — the tool tears them out of the soft matrix rather than cuts through them.

The same babbitt refinished with a diamond shows few if any tool marks at the same magnification, and all the hard crystals so necessary for a proper bearing are cut cleanly through without loosening their setting. Obviously, such a babbitt as this is in excellent shape for prompt service at maximum duty; the other must be "run-in" to wear away the soft matrix and expose some of the hard crystals so necessary to carry the load.

Babbitt metal specifications of White Motor Co. call for virgin metals in the ingots purchased. Chemical composition must be held to close limits and impurities must be held to the absolute minimum. These precautions are necessary to meet the severe conditions imposed upon the connecting rod bearings of a big truck used for heavy duty work.

Several ingots are selected at random out of each shipment, and are analyzed for copper, antimony and lead before acceptance. Tin is reckoned by difference. Exclusion of impurities, such as iron, arsenic, and bismuth, is accepted upon statement of the manufacturer. Lead content is closely watched, lest the bearing become too soft for long service.

White Motor Co.'s bearing metal specifications call for the following analysis: Tin, 87.25% minimum; copper, 5.50 to 6.0%; antimony, 6.50 to 7.0%; lead, 0.35% maximum; iron, 0.08% maximum; arsenic, 0.10% maximum; bismuth, 0.08% maximum; aluminum, none; and zinc, none.

Babbitt metal made from virgin metals according to this composition is fine-grained, and is fluid at the casting temperature. This babbitt metal has proved very satisfactory.

Operator at Open Fixture Shows Method of Casting Babbitt in a Spinning Bearing

HIGH CHROMIUM STEELS

carbides and inclusions

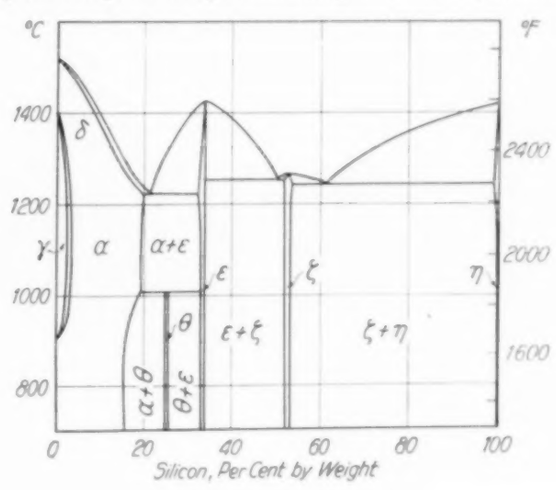
by A. Westgren
Stockholm, Sweden

QUITE a number of X-ray investigations of alloyed steels have been performed during recent years. Some general results have already been noted in METAL PROGRESS in July and August — for instance, that quenched austenitic steels have their metal atoms arranged in a face-centered cubic lattice.

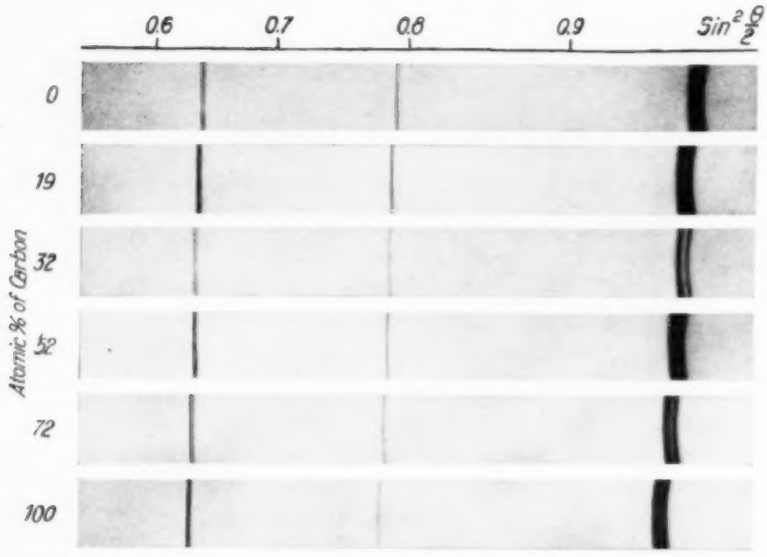
Another result of general significance is the observation that in many alloy systems, such as Fe-Si, Fe-Cr, Fe-W, and several others, the homogeneity region of the γ-phase is a closed area. Oberhoffer explained (as early as 1924 in *Stahl und Eisen)* certain observations concerning the recrystallization of the iron-silicon alloys by assuming that α-iron and δ-iron crystallize in the same lattice, and that the transformation points A_3 and A_4 should approach one another with increasing percentages of silicon, to coincide at about 2.5% silicon. Above this limit the α and δ ranges merge into one common domain.

By means of Laue photograms of very coarse grains of iron-silicon alloys containing more than 3.5% silicon, G. Phragmén was able to prove that they were true crystal individuals, thus fully substantiating the correctness of Oberhoffer's hypothesis. (Phragmén's Fe-Si diagram is reproduced from the *Journal* of the Iron and Steel Institute, 1926.) Thus, it is plain that Hull should have obtained his negative result when he tried to find out the structure of γ-iron by studying iron alloyed with about 3.5% silicon.

Iron-Silicon Diagram Shows That Alpha and Delta Regions Merge in Alloys Containing 4 to 15% of Silicon



Of course, a general survey of alloy steels cannot be given here. It may be sufficient to present a brief account of the equilibrium conditions of one impor-



Powder Photograms of a Series of Pure Iron-Chromium Alloys Show an Unbroken Series of Solid Solution with Gradually Increasing Spacing Between Atoms in the Crystal Lattice

tant system, which could hardly have been mapped without the aid of X-ray photograms. The iron-chromium-carbon system is chosen for this purpose, as it has been studied most thoroughly, and has great industrial interest.

The main object of an investigation started some years ago by the writer in collaboration with G. Phragmén and Tr. Negresco was to decide which phases are present in the system, to characterize them, but most of all, to establish under what conditions each of them is present. An account of these studies has been published at some length in the *Journal* of the Iron and Steel Institute in 1928.

The first step was to study the binary Fe-Cr and the Cr-C systems. As could be expected, and as may be proven by the series of photograms on this page, the iron-chromium alloys form an unbroken solid solution. The lattice dimensions vary continuously from 2.86 Å at pure iron to 2.88 Å at pure chromium. The photograms also confirm the statement which E. C. Bain made in the 1926 *Transactions*, A.S.S.T., that the γ-transformation is suppressed by an addition of about 15% chromium to carbon-free iron.

A series of X-ray films of chromium-carbon alloys is presented on the opposite page to show that there are three different carbides present in this system. The one containing the most carbon, Cr_3C_2, has an orthorhombic structure; its unit cell is a rectangular parallelepiped; it contains 20 atoms, and the edges of the unit cell measure 2.821 Å, 5.52 Å, and 11.46 Å. Another carbide seems to have the formula Cr_7C_3. It is trigonal; its elementary prism probably holds 80 atoms, and has the following dimensions: Basal edge 13.98 Å, height 4.523 Å. The carbide with the lowest carbon content has a composition which probably corresponds to Cr_4C. It has a face-centered cubic lattice with a parameter of 10.638 Å.

The Cr-C system is peritectic. On the solidification of a molten mass with composition corresponding to the formula Cr_4C, primary crystals of the trigonal carbide Cr_7C_3 are obtained, together with secondary crystals of the cubic carbide Cr_4C, enclosed in a eutectic formed by the cubic carbide and chromium metal. At a sufficiently high rate of cooling, peritectic structures may be obtained even in alloys which have 1 to 2% less carbon than that corresponding to the formula Cr_4C. This was originally established by means of the X-ray photograms, such as the fourth from the top in the series illustrated, but was later confirmed also by photomicrographs of strongly etched alloys.

After the three binary diagrams were fairly well understood, the next problem was the ternary alloys between iron, carbon and chromium. A great number of them were investigated by means of X-ray analysis and microscopically. Some residues obtained after partial solution in dilute acids were also studied.

In such work the X-ray, microscope, and chemical analysis are mutually indispensible tools. X-rays can identify the phases in an alloy more certainly than a microscope, because

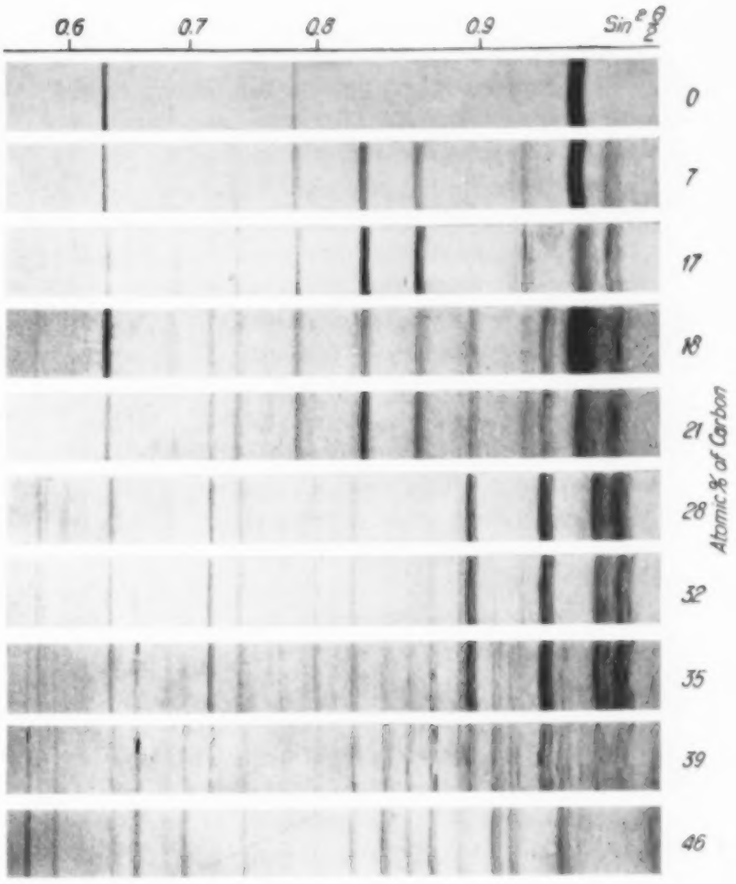
Structure at 175 Diameters of Chromium With 6% Carbon. Deep etching is necessary to show that it has a peritectic structure, containing primary crystals of Cr_7C_3 and secondary crystals of Cr_4C enclosed in a eutectic of Cr and Cr_4C

changes in composition might or might not change the degree of coloring obtained by etching. The microscope, however, shows which phase is first separated.

It was thus possible to determine the projection of the liquidus surfaces upon the composition plane of a ternary equilibrium diagram. Such a projection is given in full lines in the figure on page 60. Some intersections of the transformation surfaces of the system are shown dotted. They were derived from X-ray photograms and photomicrographs.

In the diagram the triangles are indicated in which the alloy, immediately after complete solidification, consists of three phases, the compositions of which are given by the corners of the triangle. It must be observed, however, that the position of these triangles has not been determined with a high degree of precision — this applies especially to the point S which represents austenite with a maximum content of chromium.

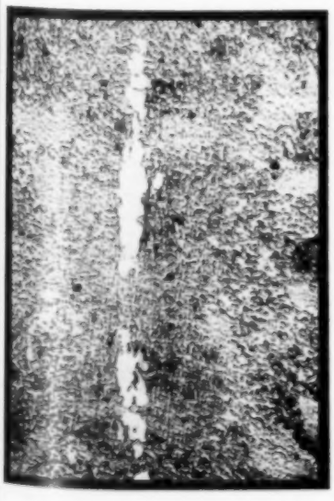
Four carbides occur in the iron-chromium-carbon system, namely, cementite (in which a number of iron atoms may be replaced in the regular position in the space lattice by chromium atoms), the cubic, the trigonal, and the orthorhombic chromium carbides (in each of which the chromium atoms may similarly be replaced by iron atoms). Of these phases only those three which are lowest in carbon may exist in equilibrium with the metallic phases. They all resist fairly well the attack of dilute hydrochloric acid, and may consequently be easily isolated from the enclosing metallic alloy by chemical means, and studied by X-rays and quantitative analysis.



Three Different Chromium Carbides Appear in These Photograms of Chromium-Carbon Alloys: Cr_4C, Cr_3C_2 and Cr_7C_3

Another diagram on page 60 shows the approximate form of an isotherm at about 700° C. The maximum content of chromium in the cementite and the maximum content of iron in the trigonal carbide are considerably reduced from that existing at solidification, as may be seen by comparing with the corresponding lines and intersections in the diagram at the left. The chromium content of the metal phase at 700° C., being in equilibrium with both trigonal and cubic carbide, is reduced to less than half its value at the moment of solidification. However, the maximum iron content of the cubic carbide seems to have increased. The latter fact was determined by some analyses carried out on carbides from stainless steel.

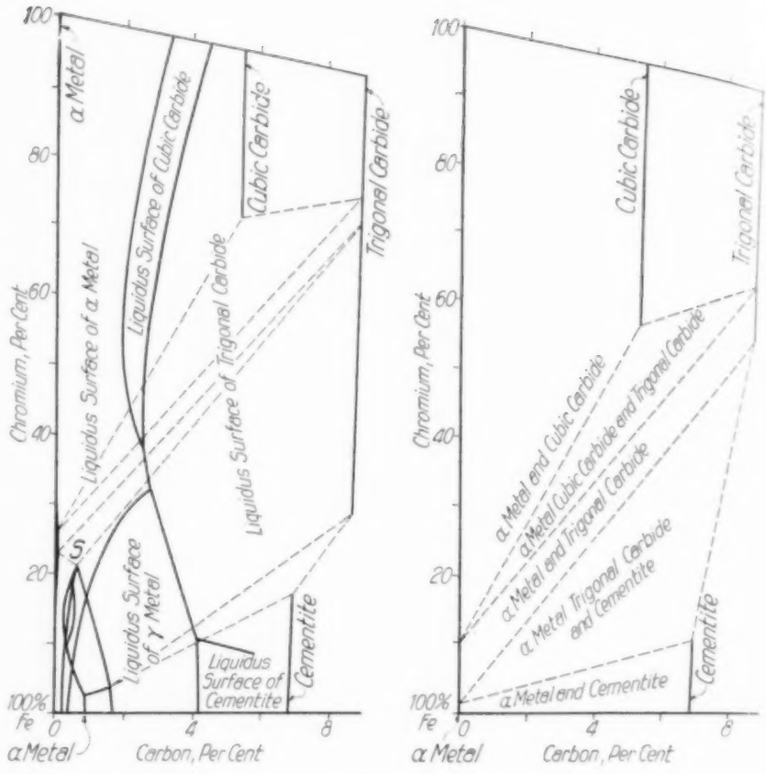
In order to give an idea of the three-dimensional diagram, the one-phase areas have been indicated in some plane sections through the ternary equilibrium model on planes representing constant chromium content. (The sketches are at bottom of page 61.) At about the same



Segregated Carbide in Ball Bearing Steel Proves to be of Same Structure as Disseminated Particles Rather Than a True "Double Carbide." They segregate during solidification of the ingot

time as the above-described X-ray results were first published, M. A. Grossmann gave a corresponding series of diagrams in a report to the A.I.M.E. (1927) on microscopic investigations of the nature of the chromium-iron-carbon diagram. His diagrams agree on the whole with the ones given here, although there is some difference in details which, however, seems to be of minor importance.

It may perhaps seem a little improper to term an investigation of this kind, which ranges over the complete ternary system, as an X-ray analysis of alloy steels, as the commercial steels and irons occupy a very small part of the ternary diagram. It is, however, necessary to be acquainted with the equilibrium conditions of almost the whole ternary system in order to obtain a complete knowledge of the constitution of the steels. When the main features of the whole diagram have been established, a solid basis is established for a more detailed investigation on its most important part, industrially speaking.



Corner of Ternary Diagram of the Chromium Steels. At left is projection of boundaries of liquidus surfaces (shown in full lines) and boundaries of transformation surfaces (shown dotted). At right is a diagram showing equilibrium conditions at 700° C.

Certain similar elaborate investigations have also been made on other systems. In the iron-tungsten-carbon system a true double carbide, Fe_4W_2C, has been discovered which is present in high speed steel. Extensive investigations of iron-manganese-carbon alloys have also been completed by E. Öhman, and the nature of the carbides in these ternary alloys has been determined.

Study of Inclusions

X-ray methods are also specially suitable for determining the nature of inclusions in steel and for researches on slag. Their applicability in this direction may be illustrated by the following example.

A chromium steel for ball bearings had been rejected on account of so-called "double carbide" or "carbide accumulation." The micrograph on page 59 shows some carbide lines in this steel. The carbides both big and little were isolated from the annealed steel by chemical means, and an X-ray photogram showed them to be cementite, in which some iron had been replaced by chromium.

A specimen of the steel was then quenched in water from about 1,000° C. The microscope showed that the "normal cementite" (the small carbide grains) was completely dissolved, while the grains of the "double carbides" were still present. These large grains were then isolated by dissolving the specimen in dilute hydrochloric acid, and a photogram of the residue was identical to the previous one. Consequently, the large carbide grains consist of the same phase as the small ones.

At first this result seemed somewhat surprising, as it had been stated that if a chromium steel containing double carbide is etched by hot sodium picrate, the small grains only will be

colored, while the big ones remain unaffected. All efforts to etch this particular steel with hot sodium picrate have, however, given negative results — that is, all the cementite grains, both the small and the large, are unattacked. The chromium content of this carbide was probably too high to be corroded by the reagent.

Later on, a ball bearing steel of foreign origin was tested. It contained 1.17% Cr, 1.13% C, and a large amount of "double carbide" which was unetched by hot sodium picrate, while the small grains were strongly colored. A similar series of tests proved that the large and small grains of carbide in this steel consisted of one and the same phase.

The fact that only the small carbide grains were etched in this second steel may possibly be accounted for by some slight difference in chromium content. The photograms seem to indicate this, but the existing data do not allow definite conclusions to be drawn, even if the variation in the lattice dimensions exceeds the limit of experimental error, as the dimensions may be influenced not only by the chromium content but also by the quenching temperature. The possibility must also be taken into consideration that the carbide may be more easily affected by etching when in a more finely divided state than when present as large grains.

Summing up, it may be concluded that the streaks of so-called "double carbide" which sometimes appear in inferior ball bearing steels are nothing but unevenly distributed cementite. The fact that the grains of carbide consist of cementite in which some iron atoms have been replaced by chromium atoms does not, however, justify the name "double carbide"; this expression should be reserved for a carbide of such a structure as *requires* the presence of both chromium and iron to build it up.

Further, it is clear that the formation of these carbide streaks in ball bearing steels cannot be attributed, as has sometimes been done, to the presence of undissolved carbides introduced by the ferrochromium into the bath of the open-hearth furnace. A study of the ingots, which have produced steels of this kind after rolling, has confirmed this conclusion. From the distribution of the carbide lines in the billets, it is evident that they have been caused by segregation during the cooling of the ingot.

Summary of Conclusions

It is hoped this series of articles has made clear the elements of X-ray metallography. A demonstration has been given of the fact that X-rays verify the postulate that metals are an aggregate of crystalline units. Then the same method has been used to discover the atomic arrangement of the various allotropic modifications of iron, of cementite, of austenite and of martensite. Finally, some results have been cited to clarify the essential constitution of the high-chromium steels.

"Double carbides" in ball bearing steels are shown to be nothing but segregated masses of cementite, in which some iron atoms are replaced by chromium, and entirely similar to the disseminated spheroidized particles.

Sections Through Ternary Model Showing Equilibrium in Alloys Containing 3%, 15% and 50% Chromium

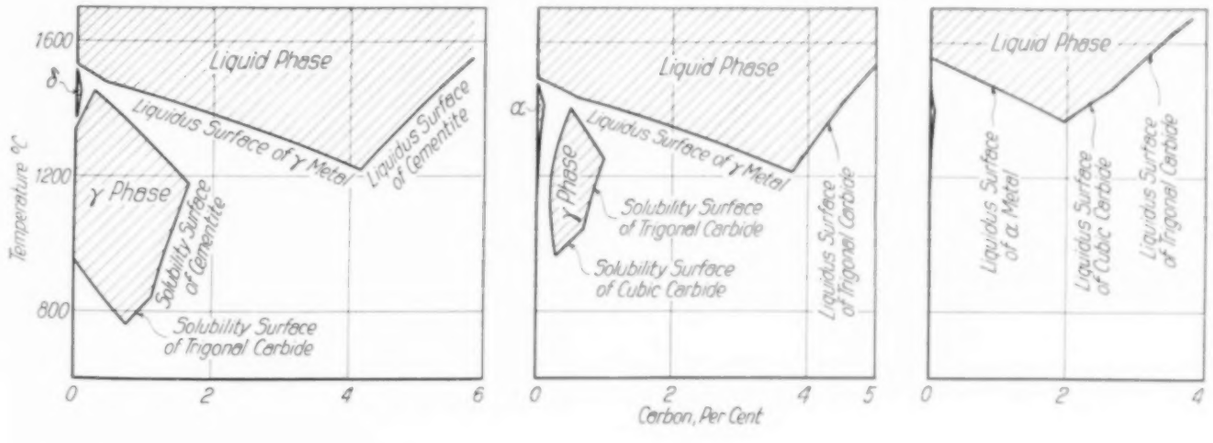


Photo by Henry M. Mayer

Steel Carries the Traffic

EDITORIAL

An Impending Revolution in Rail Making

A PARALLEL has frequently been drawn between the metallurgical problems of ordnance officers and of railroad operators. Artillerymen have the eternal competition between bullet and armor — every improvement in the one calling for a drastic change in the other. No sooner has a new and tougher plate been produced than a more powerful gun and more penetrating projectile appear.

Railroad men, for their part, witness a similar competition between rail and rolling stock. Originally straps of iron fixed to wooden stringers or edging parallel stone walls were quite good enough for horse-drawn wagons. But the 1829 trial of the "Stourbridge Lion" on the Delaware & Hudson tramway, while a complete success as far as this first locomotive was concerned, was a complete failure on the part of the track.

Immediately the rolled iron T-rail was invented, and carried the traffic for many a day. Eventually, however, the increasing wheel loads got the better of the argument. In the words of an 1873 committee of the Civil Engineers: "An iron rail is knocked to pieces before it is worn out. Our iron rails do not give out from want of strength, but from injury to head, not always perceptible to the eye."

Providentially, the bessemer steel rail was ready. Higher and higher carbon gave the increased strength and durability under steadily increasing wheel pressures. In the course of time this metal reached its limit — it was too brittle for impact of heavy trains at high speed. Again the rolling stock had won!

Another revolution in metal manufacture then occurred. In order to eliminate phosphorus and restore the maximum toughness of high carbon steel, the basic open-hearth process was perfected and soon became the standard for rails. Temporarily the problem was solved. By large increases in cross-sectional area, the rails were made strong and stiff enough for the passing traffic. But before many years dangerous defects called transverse fissures were discovered. The earlier dilemma had reappeared: "Our open-hearth steel rails do not give out from want of strength, but from injury to the head, not always perceptible to the eye." Intense pressures between wheel treads and rail were over-straining the latter, causing the steel to flow at the surface, and wedging apart the metal at any tiny internal imperfection.

Despite an enormous amount of study, no one yet knows why some heats of rail steel are immune from internal fissures while rails in other heats develop them freely and quickly. A person who is charmed by the analogies of history would say it is time now for a fourth revolution in rail making. Some melting process or some alloy or some heat treatment is needed which will give metal (not 80% of the time, nor 90%, but 99.99%) capable of resisting cold work and gradual deformation from rumbling wheels.

Some interesting studies have been made about the economic size of rails to use for a given traffic. A. N. Reece, chief engineer Kansas City Southern Railway, has shown that the added depreciation and interest on bigger rails and fastenings is recovered by savings in maintenance, tie renewals, lower costs of car repairs due to smoother track, and lessened train resistance. The lowest cost for 60,000-lb. wheel loads is found to reside in 135-lb. rails. If Mr. Reece's computations are correct, the Pennsylvania Railroad is quite conservative in adopting a 152-lb. rail for 100,000-lb. axle loads at a speed of 100 miles per hr. (These conclusions, it must be remembered, are based upon the unproven premise that the present carbon steel rails *can* carry safely the increasing loads.)

Mr. Skillman, in the article beginning on page 37, mentions his effort to increase the area of contact between rail and wheel tread. Undoubtedly, the ability of carbon steel rail to stand the expected punishment was carefully considered by his committee. Definite experience will be needed to discover whether the palliative of a rail top with a broad sweep (and the constant use of a successful flaw de-

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tector) will remove the hazard of unpredictable rail failures. A derailment of a passenger train at 100 miles an hour is not pleasant to contemplate.

Past decisions whether or not to use alloy or heat treated rails have been made on the basis of whether the large added cost could or could not be recovered in increased service. They also rest on the before-mentioned premise that carbon steel *can* carry the loads. The drive toward heavier trains to reduce ton-mile costs, and toward faster service to compete with motorcar and airplane, might readily produce loads and speeds that impose stresses which eutectoid steel, as rolled, *cannot* withstand. When that time comes, if it is not already here, the demand of railroad executives must be for a new rail which can safely carry the traffic, rather than for a carbon steel at a fixed price.

Gas Welding Moves Forward

PRIOR to the War nearly all welding (other than that done by hammer and forge) was with the oxy-acetylene flame. Repair and salvage of essential equipment in those busy days exhausted the supply of essential gases, and the electric process, as an alternative, received a strong impetus. Promoted by several equipment manufacturers with adequate research facilities, the arc process was rapidly improved, and consequently it has become increasingly esteemed.

We therefore have witnessed two pronounced trends. One is the extremely large increase in the amount of welding being done, not only by maintenance departments, but also in fabrication processes. Second is the more rapid expansion of the various electric welding processes until they have outstripped their predecessor, especially in the fabrication of steel.

It should not be inferred that the oxy-acetylene method has not been improved, for this is farthest from the truth. Continuous study has increased its versatility in pace with the growing use of special irons, steels, and alloys, so that today the blowpipe may truly be called the universal tool of the metal worker. Hence its continued predominance in maintenance work, where a variety of metals is encountered daily, and in the fabrication of nonferrous metals and high-chromium alloys.

The issue between arc welding and ox-welding (as it may be termed for short) is drawn most sharply in the fabrication of articles of steel plate—tankage and pipe, for instances. Electric welding has all but preempted this field, for two reasons: First, automatic machines have been devised which cut costs to a minimum. Second, the heat liberated is intensely localized so that the plate and the welding machine do not warp. Ox-welding offers, to counterbalance these factors, a superior quality of metal in the joint (when compared to the usual deposits from bare electrodes).

It is a curious fact that the oxy-acetylene flame does not seem to lend itself to automatic operation. True enough, successful machines for forming tubing from thin strip and gas welding the abutting seam have been in operation for 20 years or more. But when this equipment is magnified in size to take a hot water boiler, say, or even larger for an oil barrel, a number of difficulties appear which many years of work have failed to remove. At any rate, such equipment has never been promoted.

Consequently, in the present state of the art, a welder requires two hands to make a good ox-weld, one for rod, one for blowpipe, whereas an arc weld may be made by any one of a dozen automatic machines without skilled hands at all. Furthermore, by the use of covered electrodes and shielded arcs, the ductility of the arc weld may be so improved that the former superiority of the gas process in this respect is disappearing.

Oxy-acetylene welding is being so vigorously promoted that this trend could not be ex-

EDITORIAL

pected to go forward unchecked. Users of welding, and observers of these industrial trends, have therefore been very much interested in recent announcements by the Linde company and its associates in Union Carbide & Carbon Corp. of a rapid and semi-automatic method of ox-welding steel pipe. According to statements made at the Boston meeting of the American Welding Society, and to films exhibited there, this new process makes high quality joints at more than twice the speed of the conventional practice and at corresponding savings in labor and gases. Furthermore, it is semi-automatic.

This new and speedy method departs from the usual operations as follows: The V between abutting joint-edges opens 70° rather than 90°; this localizes the heat and minimizes the volume of metal to be added. (Joints may be backed up by a thin steel strip to stabilize the rather delicate equilibrium between "adequate penetration" and "protruding icicles.") The welding flame has a considerable excess of acetylene, which apparently carburizes the sloping faces of the V so they reach a "sweating" condition or incipient fusion sufficient to alloy with the advancing puddle at a temperature considerably below the melting point of low carbon steel. Hence, the amount of heat required for proper "penetration" (and therefore absorbed by the base metal) is further minimized. Next, the welding rod rides with its end scraping bottom in the joint, and is preheated to a bright red by an auxiliary flame. Finally, the welding rod is a silico-manganese steel; self-fluxing because the silicon and manganese oxidize in preference to the carbon.

These essential elements — blowpipe tip, preheating flame, and welding rod — are kept in proper mutual positions by a simple fixture. The welder's hand, which formerly manipulated the rod, is now free. Obviously, this is the first long and essential step toward complete mechanization, so necessary to place the oxy-acetylene process on competitive footing in metal manufacturing departments of industries.

An Opportunity for the Iron & Steel Institute

GOOD news comes from Pittsburgh. The five-year research on open-hearth steel manufacture, just concluded, is to be extended for another 12 months with a budget (already guaranteed) 85% that of last year. Fifty-six firms, most of them metal producers, have subscribed to the fund in the past three years, and of last year's subscriptions all but a sum of $200 has been paid. Consequently, the finances for 1932 are assured.

Now that many of the fundamental problems are reasonably well solved, the Bureau of Mines has withdrawn. Future laboratory studies into the effect of inclusions on the physical properties of steel will be conducted in facilities owned by the various cooperating firms, and at Carnegie Institute of Technology (which will also continue its work on iron-manganese and complex iron-chromium alloys). Plant investigations will also be vigorously pressed, to translate the findings of the physical chemist into procedures the melter can follow, and to experiment with some new deoxidizers.

No one who has cooperated in this work doubts its value. Nor should it be assumed that the present studies will exhaust the possibilities of research into the fundamentals of steel manufacture.

Therefore, it becomes pertinent to ask, "What of the future?" Resignation of the Bureau of Mines, while regrettable, may serve to emphasize the fact that there is a limit to volunteer effort by interested bystanders. Improvement in steel, in iron, and advancement of the science of manufacturing is properly a burden to be assumed by the producers. Yet the industry's research staffs are occupied with plant investigations. Such study as is being done on the properties of the metal is generally conducted by users or engineering societies.

It is time the industry itself, through its own American Iron and Steel Institute, should set up a representative group to pass upon suggested lines of fundamental research, and provide ways and means for their vigorous prosecution. The Pittsburgh studies have shown the way; it is now up to the Institute to continue the good work.

BOLTS, SCREWS & NUTS

materials and manufacture

by Recommended Practice Committee

A TABULATION below gives the trade classification of the bolts most frequently used, together with the steels from which they are made. All steels are S.A.E. specifications except 1118-A, 1112-B, and 1115-C. (For convenience a tabulation of chemical analysis is appended.)

Steels printed in italic would ordinarily be furnished by the manufacturer unless otherwise specified. Where two or more steels are printed in italic for the same product, the selection of the steel is optional. There is no accepted practice for connecting rod bolts.

Here it may be emphasized that this report is not intended for a specification and should not be interpreted as such. It is a tentative recommended practice and will remain tentative for at least one year until adopted by the Board of Directors and Recommended Practice Committee of the A.S.S.T.

Classification	Steels
Cap screws	*1010*, *1020*, *1035*, *1112*, 1120, 2330, 3135
Carriage bolts	*1010*, *1020*, *1118-A*, 1035
Connecting rod bolts	2330, 3135
Lag screws	*1010*, *1020*, *1118-A*
Machine bolts	*1010*, *1020*, 1035, *1118-A*, 2330, 3135
Machine screws	*1010*
Plow bolts	1010, *1020*, *1118-A*
Rim and hub bolts	1010, *1020*
Rivets	*1010*
Set screws	*1010*, *1112*, 2330, 3135
Step bolts	*1010*
Stove bolts	*1010*
Track bolts	*1025*
Nuts	*1112*, 1112-B, 1115-C

Steel S.A.E. 1010 is used for most commercial bolts and cap screws made by the cold heading process, and where strength is not the governing factor. Its minimum tensile strength is 50,000 lb. per sq.in. (Physical properties quoted are all based on machined tensile specimens.) Tensile strength of bolts made from this steel is varied by the size of the material, by the process of manufacture, and the heat treatment. This steel is also commonly used where case hardened bolts are required.

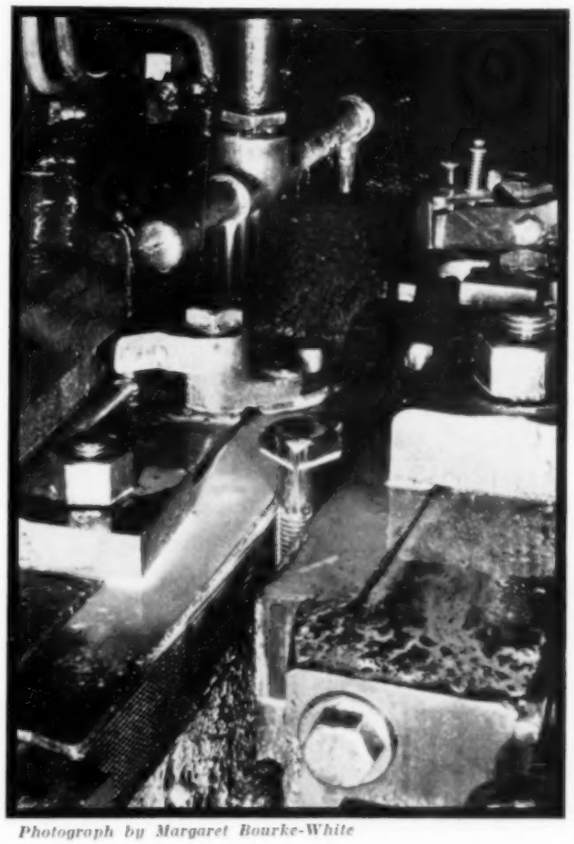
Steel S.A.E. 1112 is used for the same purposes and reasons as 1010, but the bolts are made by the screw machine process. Products milled from cold drawn bars of this steel will have an approximate yield point of 70,000 and an ultimate of 80,000 lb. per sq.in. When normalized, the approximate tensile strength is 60,000 lb. per sq.in. When cold drawn, the yield point of this steel is close to its tensile strength.

Open-hearth steel of practically this analysis is used for nuts made by the cold punched process. It is not an S.A.E. steel, but is listed as 1112-B in the accompanying tabulation.

Steel S.A.E. 1020 is generally used for cold headed bolts where a higher tensile strength is

required than bolts made from S.A.E. 1010. Tensile strengths will be found to vary greatly between bolts made of the upper and lower carbon limits of the analysis. The usual tensile strength of the heat treated bolt is 80,000 and the yield point 60,000 lb. per sq.in. Because of the severe service demands, plow bolts are always heat treated when made from this steel. This steel is frequently used in the cold drawn condition for the manufacture of screw machine products. It then has a tensile strength of approximately 75,000 and a yield point of 60,000 lb. per sq.in. This is normally the highest carbon steel from which nuts are produced. Where additional strength in a nut is required it is usually obtained by increasing the thickness.

A steel of practically this analysis, but with high sulphur, listed here as 1115-C, is generally used for the production of nuts made by the hot punched process. When an open-hearth steel is preferred to a bessemer product, this steel replaces 1112.



Photograph by Margaret Bourke-White

Roll Threading Machine at Russell, Burdsall & Ward Bolt & Nut Co. Plant

Steel S.A.E. 1035 is used for cold headed bolts where a higher tensile strength is required, and where severe service conditions must be resisted.

After a suitable heat treatment, the minimum tensile strength is 100,000 lb. per sq.in., combined with good ductility (minimum of 12% elongation in 2 in. and 45% reduction of area). Brinell hardness range of 196 to 269 is found to be satisfactory for most classes of work. This is the highest carbon steel generally cold headed and the lowest carbon steel satisfactorily double heat treated to close limits. It is also used for screw machine products.

Products made from the S.A.E. steels 2330 and 3135 are used to resist fatigue and shock and where a minimum tensile strength of 125,000 lb. per sq.in. is required. After suitable heat treatment, the average physical properties obtained with these steels are as follows: Yield point, 110,000 lb. per sq.in.; tensile strength, 140,000 lb. per sq.in.; elongation, 16% in 2 in.; and reduction of area, 55%. Brinell hardness ranges of 228 to 269, 241 to 286, and 269 to 321 are usually specified, depending upon requirements.

For special purposes bolts are made from stainless, noncorrosive, and nonferrous metals.

Some general remarks on manufacturing processes will now be appended.

Cold heading is a process of upsetting by which the steel is made to flow into various shapes while it is cold.

Two types of machines are used, (a) the solid die type, and (b) the open die type.

As a general rule, the solid die machine is used where the product is of short length and also where it is of medium length if it requires high grade finish with close tolerance limits. The open die is usually employed for long lengths of work which cannot be handled successfully in the solid die machine. Both types of machines are designed to operate with one or more heading strokes; the number of strokes

required depends upon the shape of head and the amount of metal to be upset.

Cold upsetting is limited by the design of head because a limited amount of metal will flow into certain shapes. Shapes with corners and squares are hard to fill.

All the steels listed in this practice, except screw stocks, are satisfactorily used for cold heading bolts.

Hot heading is similar to cold heading except that the steel is upset while it is hot.

Trimming. When the round or button-shaped head has been upset in the cold heading operation, but some other shaped head is desired, such as hexagonal or square, it is secured by a trimming operation. This consists of forcing the upset button head through a die of the required shape.

Burnishing sometimes follows the trimming operation in order to obtain a smoother finish on the side of a head. This consists of forcing the head of the bolt through a second die of the same shape as the trimming die, but of slightly smaller size.

Shaving and pointing. If the top and bottom of the heads have not been properly shaped in the heading operation, they can be finished in a shaving operation, which consists of cutting the top and bottom of the heads to desired form. This is particularly true of cap screw blanks.

Pointing or chamfering the end of the body of bolts or screws is accomplished by holding the blank in a suitable fixture and machining the end to the desired form. This operation prepares the blank for threading and gives the proper finish to the threaded end of the bolt as well as facilitates easy entrance into a tapped hole.

Threading. Threads are cut by holding the bolt in a suitable fixture and presenting it to a die head which contains chasers. The chasers cut the threads on the bolt. When the desired length of thread is cut, the die head opens and releases the work.

Roll threading is accomplished by rotating the blank between flat or circular dies, upon the faces of which angular grooves have been cut which correspond to the proper form and lead of the thread to be rolled. These dies form the thread by displacing stock from below the pitch diameter of the thread and filling out the crest of the thread with the displaced metal.

Two diameters of wire may be used for roll threading. In the first method the original wire has a diameter corresponding to approximately the pitch diameter of the threads, and the smooth shank of the blank is upset to the nominal diameter of the screw in the heading die. In the second method full-sized wire is used and the threaded portion reduced by extrusion, swaging, or shaving operations until the outside diameter of the resulting thread will match with the smooth shank.

Heat treatment of screws, bolts, and nuts made from carbon steels may best be done according to the recommended practice for the heat treatment of S.A.E. carbon steels, National Metals Handbook, 1930 edition, pages 132 to 136.

Set screws made from carbon steels are case hardened.

Products made from 2330 steel are quenched in oil from 1,475 to 1,525° F. Products made from 3135 steel are quenched in oil from 1,500 to 1,550° F. All would be tempered according to the requirements of the finished bolts.

STEELS FOR BOLTS, NUTS AND SCREWS

Steel Number	Carbon	Manganese	Phosphorus Max.	Sulphur Max.	Others
1010	0.05 to 0.15	0.30 to 0.60	0.045	0.055	
1020	0.15 to 0.25	0.30 to 0.60	0.045	0.055	
1025	0.20 to 0.30	0.50 to 0.80	0.045	0.055	
1035	0.30 to 0.40	0.50 to 0.80	0.045	0.055	
1112	0.08 to 0.16	0.60 to 0.80	0.09 to 0.13	0.075 to 0.15	
1112-B	0.09 to 0.15	0.50 to 0.80	0.04	0.10 to 0.13	
1115-C	0.10 to 0.20	0.50 to 0.80	0.09	0.075 to 0.15	
1118-A	0.14 to 0.22	0.60 to 0.90	0.045	0.075 to 0.12	Si 0.075 to 0.15
1120	0.15 to 0.25	0.60 to 0.90	0.06	0.075 to 0.15	
2330	0.25 to 0.35	0.50 to 0.80	0.04	0.05	Ni 3.25 to 3.75
3135	0.30 to 0.40	0.50 to 0.80	0.04	0.05	Ni 1.00 to 1.50 Cr 0.45 to 0.75

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This tentative recommended practice has been passed by a subcommittee of the Recommended Practice Committee, A.S.S.T., having the following personnel: C. F. Newpher, chairman, A. E. Buelow, W. C. Cooke, L. E. Guscott, Samuel Hersch, T. S. Higbee, H. B. Pulsifer, and E. M. Slaughter. Criticisms and suggestions will be welcomed by J. E. Donnellan, secretary, 7016 Euclid Ave., Cleveland.

FE — MN — NI — C

a new

manganese steel

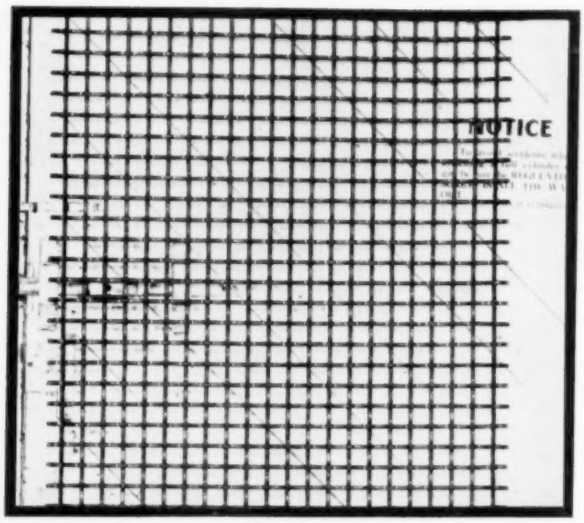
by John Howe Hall
Technical Assistant to President
Taylor-Wharton Iron & Steel Co.
High Bridge, N. J.

HADFIELD'S manganese steel, as made for nearly fifty years in both cast and rolled forms, contains from 10 to 14% manganese and from 1.10 to 1.40% carbon. Because of its comparatively high carbon content, the microstructure of the steel before heat treatment consists of austenite plus a considerable amount of free carbide or cementite. The carbide is hard and brittle, and, by breaking up the continuity of the austenite ground mass, its presence results in a brittle metal. To dissolve the carbide, manganese steel articles are heated to above 1,800° F. and quenched in cold water, which results in a steel wholly austenitic in structure, extremely strong and tough.

This drastic but necessary heat treatment, and the readiness with which the carbide reappears if the toughened steel be again heated to a comparatively low temperature, have set certain definite limits to the use of this steel in industry. It has a high coefficient of thermal expansion and a very low heat conductivity (about one-seventh that of carbon steel), so there is a great difference in the cooling rates of exterior and interior of a piece during quenching. This sets up stresses of such magnitude that sections of manganese steel over 5 or 6 in. thick cannot be quenched without producing cracks, which generally start within the body of the piece and work toward the surface.

Furthermore, if treated and toughened manganese steel is subjected for several hours to a temperature even as low as 575° F., the carbide held in suspension by the quenching is liberated as fine needles distributed throughout the austenitic ground mass. At higher temperatures the carbide separates out more rapidly. This liberated carbide so breaks up the continuity of the steel as to make it exceedingly brittle. Manganese steel, therefore, cannot be successfully applied in service where it is exposed for a long time to temperatures of 600 to 700° F., or for a short time to temperatures above 800° F.

To avoid these two difficulties, it was necessary to modify the composition of manganese steel so it could be made austenitic, strong, and tough by cooling in air after annealing, instead of by quenching in water, and so there would be no embrittlement of the metal on subjecting



High Manganese-Nickel Steel Wire Which Can Be Crimped Cold Makes Excellent and Durable Screens

it to temperatures up to a dark red heat. Fortunately, both these qualities were found in a single alloy, the modified manganese steel developed in the laboratories of the Taylor-Wharton Iron & Steel Co., and known as "Tisco Timang" steel.

This metal exhibits the usual characteristic properties of standard manganese steel and similar power of resisting heavy wear of many kinds, but is heat treated by a simple normalizing process, and retains its strength and toughness after exposure to temperatures up to 1,100° F. These desirable properties have been secured by combining some 3 to 5% of nickel with the manganese of the standard Hadfield manganese steel, and at the same time lowering the carbon to about the eutectoid ratio, so there is little, if any, tendency for carbides to separate on heating to low temperatures.

Average physical properties of this new manganese-nickel-carbon steel, as shown by tensile test bars cast to shape and hand ground roughly to size, and by tensile bars ground to accurate size from a coupon provided with a heavy feeding head, are shown below.

	Rough Cast	Finish Ground
Tensile strength	97,000	105,500
Proportional limit		
Tension		27,500
Compression		31,000
Elongation in 2 in.	30.0%	56.9%
Reduction of area	23.2%	48.3%

Rough cast bars will bend 180° and their Brinell hardness is 170.

Limit of proportionality, as determined with an Olsen extensometer, is given above, because yield point determinations for this and other cast manganese steels are next to impossible to make accurately, and such determinations as have been made are of more than doubtful value.

PROPERTIES OF WIRE

Size	Condition	Tensile Strength	Yield Point	Elongation
0.003 in.	Hard drawn	314,000		
	Annealed	185,000		
0.008 in.	Hard drawn	308,250		2.6 in 8 in.
	Annealed	148,400		6.0 in 10 in.
0.018 in.	Hard drawn	303,600		4.06 in 8 in.
	Annealed dead soft	133,000		39.4 in 8 in.
0.064 in.	Hard drawn	252,600	220,250	1.1 in 12 in.
	Annealed	197,500	143,000	14.8 in 10 in.
0.057 in.	Hard drawn	263,500	214,900	4.0 in 2 in.
0.071 in.	Hard drawn	239,400	192,000	5.0 in 2 in.
	Annealed	207,200	152,300	15.5 in 2 in.
0.102 in.	Hard drawn	232,100	216,400	9.2 in 2 in.
	Annealed	249,000	191,000	7.5 in 2 in.
	Soft annealed	189,500	152,300	21.4 in 2 in.

TENSILE PROPERTIES AT HIGH TEMPERATURES

Temperature of Test	Tensile Strength	Elongation in 2 in.	Reduction of Area
1,800°F	9,000	66.5%	68.7%
1,900	7,350	84.0	89.4
2,000	5,800	113.5	100.0
2,100	4,500	90.0	91.1
2,200	3,650	100.0	91.5

Careful determinations of the resistance to wear have been made in the Taylor-Wharton laboratories, and it has been found that, from this standpoint, the new Timang alloy and standard manganese steel are closely similar, both resisting heavy wear from six to ten times as long as ordinary carbon steels.

Installations of normalized cast Timang steel that have been made include hot bed run-out tables, forming dies for lap welded pipe, coke oven shovels, draw bench chain in butt-weld tube mills, and many similar applications where the steel is called upon to resist wear and a considerable amount of heat.

In one plant a manganese steel draw bench chain had broken frequently, especially when

PROPERTIES OF ROLLED SPECIMENS

Size	Condition	Tensile Strength	Yield Point	Elongation	Reduction of Area	Brinell	Single Shear
1 in. round	As rolled	138,550	41,250	83.0 in 2in.	49.6%	185	
¾ in. round	As rolled	153,000	58,000 *	69.3 in 2in.	44.0	169	
⅞ in. round	Normalized, 1000°C.	103,900	41,100	44.6 in 4in.	29.4		
½ in. round	As rolled	156,000		33.0 in 10in.			
¼ in. round	Hammered	136,700	55,600	57.0 in 2in.	38.9	286	
⅛ in. plate	As rolled	145,300	78,150	36.6 in 4in.	32.7	255	100,000
⅛ in. plate	Normalized, 1000°C.	108,100	47,300	47.8 in 2in.	34.8	228	98,400

* Proportionel Limit: 50,900 lb. per sq. in.

the mill was started up after the week-end shutdown. Where no other metal had been found that would stand up to the service, chains of the new alloy have been in service for several years without a single breakage, and have resisted successfully the heavy wear to which they are subjected.

New Alloy Easy to Work

In the form of wire, rod, and plate, "Tisco Timang" steel has proved itself even more successful than in castings. Far less difficulty is experienced in rolling the ingots than in rolling standard manganese steel. Since plain normalizing is all that is required to toughen it, heat treatment is seldom necessary and the steel is used as it comes from the rolls. Izod impact strength of ¾-in. round rods, as rolled, is 118.3. In this condition sheet and plate from $\frac{1}{32}$ to ⅜ in. thick can be bent flat on itself without cracking. Regular rolled manganese steel has to be heated to a high temperature and quenched in water in order to toughen it properly, and even in this condition it will not bend double without some cracking around the outside of the bend.

The physical properties of Timang steel in the form of wire, rod, and plate, and in various conditions, are shown in accompanying tables. The data were obtained in our laboratories except for wire, which were contributed from several sources.

Magnetic permeability of the rolled alloy drops from 1.030 to 1.020 as the magnetizing force increases from 50 to 300 gilberts per cm. Electrical resistivity of wires at 20° C. is 70.6 in the hard drawn, and 67.0 in the annealed condition.

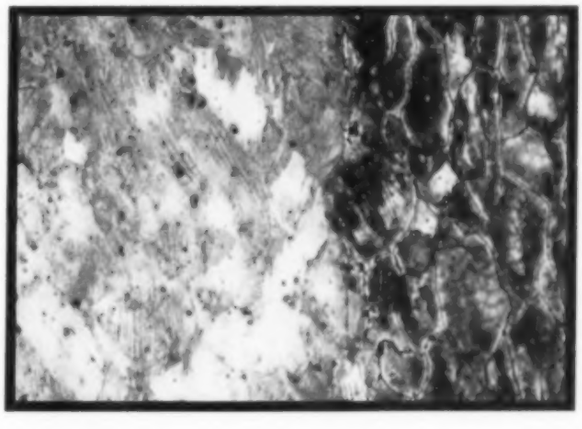
Average coefficient of expansion in the range 20° to 100° C. is 0.0000187 per degree; in the range 20° to 500° C. it is 0.0000222. Specific gravity of ¼-in. round, as rolled, is 7.864. The melting range has been determined as 2,410° to 2,500° F.

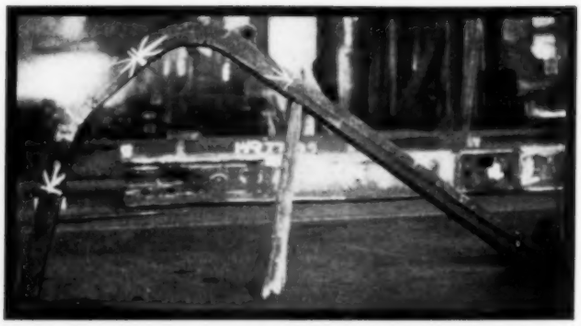
The ease with which this austenitic steel can be shaped and bent cold has made it a desirable material for many wearing parts made of plate, such as journal box liners, pedestal gib liners, and other similar parts for cars, and for chute and hopper liners in ore and stone crushing plants. It has proved particularly successful for screens woven from wire or rod, especially in view of the fact that the rods are crimped cold, whereas many screens can be made from standard manganese steel only by the troublesome and costly process of crimping the bars hot.

Good for Welding Rod

The air toughening properties of Timang steel suggested its use as a welding rod for repairing cracked or worn manganese steel machine parts. Tests soon indicated its value.

New Austenitic Alloy is Very Good for Welding Hadfield's Manganese Steel. Micro at 100 diameters shows weld metal at joint with base metal





Toughness and Strength of Welds in Manganese Steel Are Shown by Bending a Repaired Switch Tongue

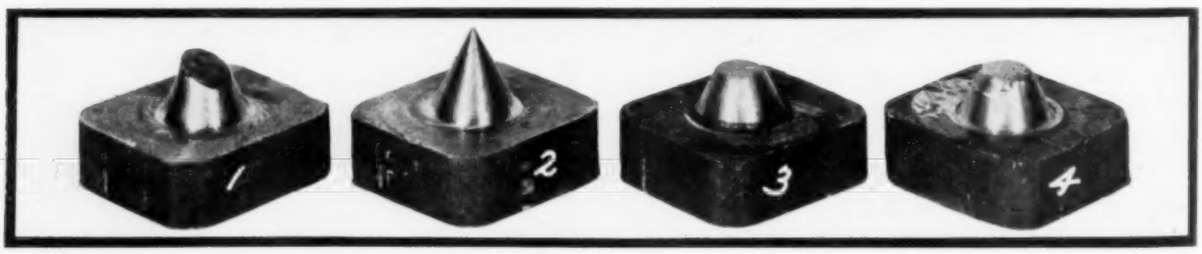
The problem of producing successful welds in manganese steel has long been a baffling one, since even perfectly sound welds of the same composition as manganese steel usually possess but a fraction of the strength and ductility of the original metal. Investigation has shown that failure usually occurs, not in the weld metal, but in the manganese steel close to the weld, the weakened metal being that portion which has been brought almost, but not quite, to the point of melting. Singularly enough, this weakness is only partly curable by re-heat treating the piece, and many apparently successful welds have been found to come out when placed in service and to bring part of the underlying steel with them.

Rods of the new alloy work easily and smoothly in welding, and produce a weld in manganese steel that has a high percentage of the strength and toughness of the original casting. To investigate this point many welds have been made in manganese steel test bars, with eight varieties of rods formerly offered as satisfactory for this service. Bars $\frac{3}{4}$x$\frac{3}{4}$ in. bent from 5° to 25° before cracking, had a tensile strength ranging about 28,500 lb. per sq.in. and an elongation of 3.2 to 5.5% in 2 in. Corresponding figures for welds in manganese steel made with Timang rod are 78° bend, 51,000 tensile, and 8.2% elongation.

To bring out even more clearly the strength and adherence of the welds, manganese steel cones 1 in. high and 1 in. base diameter, with a rectangular base 2x2x$\frac{5}{8}$ in., were cast and ground to exact size. The cones were then ground off at an angle of 30° to the horizontal, as shown at 1 in the photograph below. The oblique surfaces were then pounded with a hammer until the hardness of the steel was raised to over 500. Cones were then rebuilt by electric welding with Timang rod and with ordinary high manganese steel rod, ground to the original size, and subjected to fifteen blows of a 30-lb. weight falling 5 ft. Both welded cones acted much alike as far as compressibility and hardening power of the deposited metal are concerned, but a glance at the figure shows clearly the superiority of the new alloy. It has not cracked or spalled in the slightest, whereas the manganese steel weld has cracked badly and started to slide down the line of the weld.

These laboratory tests have been confirmed by hundreds of successful welds of castings. In both steam and electric railway service, worn frogs and crossings have been restored to their original shape by electric welding with the new rod, and have lasted for many months without spalling or cracking, as is so common in welds made with manganese steel rod. One figure shows a bend test on one of these welded manganese steel switch tongues, which had stood up for months under heavy interurban cars.

Ends of Manganese Steel Cones Were Ground Off and Hammered to Brinell 525. Points were then built up by welding; deposited metal was about 175 hard. Ends were then flattened by 15 blows of falling tup. Welds with Timang (3) and Hadfield (4) steel both hardened under this treatment to 490 Brinell, but the latter shows evidence of spalling away from its base metal



CORRESPONDENCE

and

foreign letters

PARIS, France — Much of the progress achieved in heat treating practice is due to the improvement and standardization of temperature-measuring instruments. The fundamental condition is that pyrometers are accurate; that is, they can be compared one against another to secure the same indication at the same moment.

Dilation Bar to Control Anneal of White Iron

Assurance as to this fact is obtained by calibrating the implements at determined intervals. In general, this involves the determination of the indications at regular points, such as the solidification temperatures of gold, silver, antimony, and other pure elements.

Such calibration is a laboratory operation which requires special apparatus and a skilled operator. Furthermore, the apparatus must be taken out of service. If the workshop uses a considerable number of pyrometers, a special technician may be employed to do nothing else but this work. Even with the best of care, a pyrometer may accidentally get out of order, and this fact is noticed only when it is needed for operation.

It is not always appreciated that the knowledge of the *exact* value of temperature is seldom necessary for workshop operations; the temperature is a means, not an end. It is enough that the pyrometer indicates on an arbitrary scale the point where the heat treating operation must take place.

To be specific: The room temperature, the zero centigrade, the regular calibration points have no direct meaning in reference to the hardening temperature of a given piece of steel. The temperature at which transformation takes place is the significant point for such an operation. Obviously, the latter can be used as a datum to control hardening operations, especially since it is in the close vicinity of the correct hardening temperatures.

This was pointed out by the writer several times during the War. We then recommended the use of the recalescent point A_1 of shell steels; it can be used during heating or during a moderately slow cooling to detect gross errors of thermocouples or radiation pyrometers. Furthermore, the work can be done in the shop without any special apparatus or expert help.

In recent years this idea has been adapted to the design of heat treating equipment. For instance, the transformation point on heating is given by the absorption of heat in the Hump method. The loss of magnetism is utilized in the "Crit-Point" apparatus and the Wild-Barfield furnace. Dilation at the transformation is used to mark a fixed point in the Chevenard and the "Volcrit" apparatus. When using such equipment the actual hardening temperature is fixed according to the piece and to the desired hardening penetration; sometimes it is a certain number of scale markings above the critical point; sometimes a certain time is measured after the point is passed and then the piece is quenched.

Generally speaking, the advantages of freezing points for pyrometer standards are that they are marked by an important and sudden escape of heat and by a negligible thermal hysteresis. Likewise, transformation points of

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steel (710° C.) and aluminum bronze (575° C.) are accompanied by a sudden evolution of heat on cooling, but they are affected greatly by the speed of cooling. Thermomagnetic anomalies or Curie points of magnetic metals and alloys have the advantage of being almost exactly reversible and consequently insensible to the speed of heating or cooling. The disadvantage is that they are accompanied by only one very small and progressive thermal change. Consequently they cannot be directly associated with pyrometric indications, yet they may be used with the help of a magnet, since permeability changes very rapidly near the Curie point. This rudimentary method has great sensitivity. A series of iron, nickel, and cobalt alloys may be used to give a complete series of Curie points for a thermo-magnetic scale.

If one of these phenomena is to be used as a pyrometric datum, the most accentuated manifestation should be chosen. Consequently, temperature should mark the melting points, dilatometric or thermal changes are best for eutectoid transformations, magnetic variation for the Curie point. Moreover, it is quite advantageous to use the phenomenon occurring in the given industrial operation. Thus, annealing of white cast iron should be controlled by the expansion of the metal since the graphitization phenomenon is marked by a considerable volume change and, consequently, dilatometry indicates it most clearly.

The duration of the anneal for complete graphitization is a function of the cast iron, of the melting and the casting conditions (all of which are poorly defined factors) as well as of the real tempering temperature, which in itself is not the temperature of the furnace but the temperature of the pieces within the boxes.

All the above uncertainties relative to the time of anneal could be avoided in the following way: It would be sufficient to use an expansion pyrometer placed in one of the annealing boxes and containing, as a pyrometric body, a small bar cast from the same metal as the pieces to be graphitized. When expansion ceases at the chosen tempering temperature, it is clearly indicated that equilibrium is reached at such a temperature, and the graphitization has been completed. Moreover, since any extension of the heating period involves an unnecessary cost of fuel, the cost of the operation may thus be reduced to a strict minimum.

ALBERT PORTEVIN

PHILLIPSBURG, N. J. — Since much discussion of the effect of small inclusions and gases in steel took place at the recent Boston convention, it may be timely to record some impressions I received on this point during a trip abroad in 1930.

Sulphur and Phosphorus in Quality Steels

Swedish steel has had a high reputation for many years. One of the points stressed, with regard to this material, has been its low phosphorus and sulphur contents — due to the purity of the raw materials. For instance, the Bispberg mine, opened about 600 years ago, is still mining ore with only a trace of sulphur in the best ore. Phosphorus ranges from 0.002% in ores containing 60 to 70% iron to 0.010% in lean ores (50% iron).

While these figures are exceptional, pure raw materials are available to all of the Swedish manufacturers and permit all of them to make steels with exceptionally low phosphorus and sulphur, some of them commanding high prices and good reputation, others of them being sold in competition with tonnage steels made in other countries. The value of such low percentages of sulphur and phosphorus has therefore never been definitely settled. In fact, an excellent quality of steel has been made in other countries with higher phosphorus and sulphur than normally found in any Swedish steel.

It is claimed that the nature of Swedish raw materials imparts a definite quality to the steel. This also has never been definitely proven, especially as no actual service tests are capable of distinguishing small differences in quality. It is recognized, however, that quality is an inherent factor and the quality of Swedish metal is due primarily to their raw materials and melting methods. Some of the manufacturers have produced an exceptionally high quality

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steel by a combination of pure raw materials, good workmanship and rigid control of the melting operation.

Jernkontoret — the Swedish iron and steel institute — has given a good deal of attention to this problem of determining quality in steel, but as yet has announced no test (aside from actual service) which can predetermine it.

M. Duval told me that the French would not consider using tool steel with sulphur as high as 0.025%; the maximum permissible would be 0.015. Phosphorus could be as high as 0.03%. His compatriots claim that the excessive oxidation of the bath necessary to lower the phosphorus is more harmful than the above amount. They work on the sulphur with a lime slag, and avoid oxidation of the bath while reducing the sulphur content.

B. F. SHEPHERD

Corrosion in Ballast Tanks and Tankers

BIRKENHEAD, ENGLAND — Corrosion of tanks in ordinary cargo vessels and in tankers has been hammered into the engineering and metallurgical worlds for many years and the latest blow was recently delivered on the North East Coast by J. Foster King and J. L. Adam in an excellent paper entitled "Corrosion in Tanks and Tankers." Most ordinary cargo ships are equipped with two deep tanks and in addition to this a certain amount of the double bottom accommodation is available for liquid cargoes; therefore the distinction between tanks and tankers need hardly be drawn. It is, of course, admitted that the tanker is carrying nothing but liquid cargoes, but nevertheless the problem of corrosion of cargo vessel tanks arises in kind if not in degree.

Use of double bottoms for carrying fuel oil was initiated during the War and, except for the difficulty caused by the presence of a small amount of water due to drainage difficulties, was extraordinarily successful. So far as corrosion was concerned there was very little trouble. In fact the opinion has been frequently expressed that the double bottom tanks were better for having carried such cargoes, in that they were clean and had a protective film of oil on their surfaces.

Broadly speaking there are four classes of liquid cargoes which tanks are called upon to deal with.

1. Light oils, such as petrol and benzine.
2. Fuel oils.
3. Lubricating oils.
4. Such liquids as soya bean oil, coconut oil, palm oil, molasses and latex.

Each of these classes has to be considered on its merits. Petrol, for example, will clean the tank down to practically bright metal. Incidentally it will also show up all the leaky rivets.

The second class of oil will do a certain amount of cleaning but will also leave an oily film which will protect the clean metal.

Lubricating oils will not do any cleaning but will leave a substantial protective film.

Each member of the fourth class has to be considered individually, but in general it may be taken as a fact that there is a tendency towards a slight attack on the steel.

Further trouble is that certain liquid cargoes solidify as temperature falls and have to be heated by means of steam coils before discharge. The comparatively high temperature so obtained combined with the free fatty acid content of the cargo all leads to attack on the walls of the tank.

An added difficulty is that as a rule liquid cargoes are only available in one direction and on the return trip it may be advisable, for purposes of trim, to fill certain tanks with sea-water. Now sea-water, given enough of it for a long enough time, is one of the most powerful corrosive agents known. Owing to the failure of the metallurgist to supply steel capable of standing up to these varied conditions the shipowner has naturally turned his attention to the application of protective coatings.

A limit is set to this practice by the fact that the coating must be of such a nature that it will not in any way contaminate the liquid cargo. Nevertheless in the last twelve months several very promising proposals have been put forward by certain paint manufacturers. But it

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is full early to pass an opinion on these things.

Some day, perhaps, the metallurgist will hand out some alloy steel which will resist these various attacks and at a price which makes it a commercial possibility.

F. G. MARTIN

Pure Tin Has No Allotropic Transformation

SENDAI, JAPAN — A controversy has existed for some time over the moot question of whether the metal tin has an allotropic modification somewhere between room temperature and the melting point. Most metallurgists have denied the existence of this presumed allotropy, but now and then someone contests this view and tries to confirm its existence from some abnormality in a physical property as it varies with the temperature. Thus, A. Goetz has found a large abnormal change in the photo-electric emission in the range between 200° and 100° C.

Dr. Yoshiharu Matsuyama has thoroughly investigated this problem by conducting parallel experiments on thermal analysis, dilatometric analysis, and measurements of electric resistance of very high sensitivity. He has also confirmed his results by X-ray photograms at high temperatures. He finds that a very pure tin showed no sign of any allotropic modification in the range from ordinary temperature up to the melting point.

The eutectoid structure which is found in low cadmium-tin alloys is often cited as an indication of allotropy. He therefore studied the tin side of the cadmium-tin equilibrium diagram by using the several physical methods in addition to ordinary microscopic observations. The equilibrium diagram he obtained is shown in the annexed figure.

It is seen from this diagram that the eutectoid structure can be explained without assuming any allotropy of tin at a high temperature.

KOTARO HONDA

International Foundrymen Meet in Italy

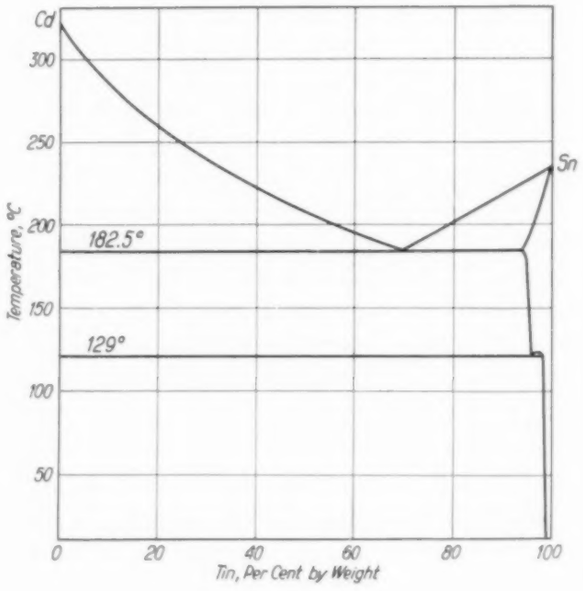
TURIN, Italy — During the first half of September, the International Foundry Congress and Exhibition was held in Milan. This is a fifth of a series, the first being at Paris in 1927, next at Barcelona in 1928, then at London in 1929, and last year at Liège. France will follow in 1932, Czechoslovakia in 1933, the United States in 1934, and Germany in 1935.

Places and dates have been chosen by the international committee of the Technical Foundry Association, which was organized in Brussels at the end of 1926, immediately after the notable meeting in Detroit. The objects of this committee include the coordination of the work of the different associations and the promotion of the foundry industry.

The exhibition this year was placed in the engineering industries building at the commercial fair grounds in Milan, a permanent building which covers an area of about 130,000 sq.ft. It was completely filled by foundry exhibits.

It was divided in five sections, the first of which included raw materials, like ores, fuels, metals, refractory materials, and molding sands. In the second were placed rough and machined mechanical castings, ornamental and art castings, and machines whose principal parts are

Cadmium-Tin Equilibrium Diagram According to Matsuyama



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metal castings. In the third section was to be found (many of them in operation) labor-saving machines and tools, such as combustion and electric furnaces for melting, drying, and heat treating, machines for the preparation of foundry sands, molding, casting, cleaning, and welding machines. The fourth section was reserved for technical teaching (especially professional schools), technical publications, and foundry organizations. In the fifth section a very interesting and curious historical exhibition was found.

Much credit for the organization of this successful meeting is due to Carlo Vanzetti, the head of one of the largest steel foundries in Italy (Fonderia Milanese d'Acciaio) and a past president of the international committee.

While I am writing this letter (September 17), the members of the Congress have left Milan for Aosta and Cogne, where they will visit the iron and anthracite mines and the iron and steel plants of the "Società Nazionale Cogne." This visit will be followed by others in various industrial districts. On the 18th the Olivetti foundries in Ivrea, next day the Fiat works and the Unica company will be visited in Turin. On the 20th and 21st, trips will be made to Genoa and the neighboring districts, to the harbor of Genoa, the works of the Ansaldo company, the Cogoleto pipe foundry and the Savona steel works of the Ilva company, the Servettaz-Basevi and the Tecnomasion Italiano engineering works. On the 22nd, the members will be in Rome, and on the 23rd will visit the plant of the Terni company. During the following days visits to the most interesting places of Rome, and excursions to different points of artistic interest in central Italy have been arranged.

After the 28th of September, the members of the Congress will divide in two groups, one of which will visit Naples and Sicily, while the other will proceed to Venice, Trieste, and the eastern Alps.

Forty-three technical papers have been presented to the Congress. Three additional reports have been read and discussed at a joint meeting with the Association of Italian Metallurgists. The subjects of the latter are "The Present Status of Electric Melting Furnaces," by O. Scarpa; "Open-Hearth Practice," by F. Fiorelli; and "Rotary Furnaces for Melting Iron," by the writer.

FEDERICO GIOLITTI

GREEN BAY, WIS. — Some of the industries served by Barker Machine Works & Tool Co., of which the writer is chief engineer, call for cast irons to resist special corrosive influence. These calls, as early as 1919, led to a series of tests on alloy cast irons, the general results of which may be interesting.

Effect of Copper in Cast Iron

We attempted to produce an iron comparable in cost to gray cast iron, yet being more corrosion-resistant. At first, these were made with chromium alloys, then with nickel-chromium, but to obtain the results required it was necessary to increase the alloy content to a point where the iron was prohibitive in cost. It was then determined to add copper to the alloy, despite the bad reputation of this metal (at least, as far as its expected influence on iron and steel was concerned). This reputation we found to be wholly undeserved.

Some nickel alloy test pieces were melted and copper added. It was found that the addition of even small percentages of copper seemed to intensify the action of the nickel. Further tests with chromium and copper showed the same thing. The addition of copper to either nickel or chromium alloy would allow the nickel or chromium content to be reduced, and still get the same effect.

A new series of tests was begun and has been carried on to date, with varying percentages of nickel, chromium, and copper alloyed with a normally white cast iron. Certain analyses gave extraordinary resistance to corrosion, at the same time gave machinable hardness with a fine texture, extra physical qualities, and low cost. We put this material into use with success.

While searching for a cheap corrosion-resisting casting, we also watched for something with superior wear resistance.

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Twenty years ago the railroads asked for irons as hard as consistent with machining, and for that reason many of the locomotive cylinders of that date (and even of today) are made of a variety of white iron. The first automobile cylinder blocks were of this type of metal, but demands of production quickly eliminated it.

Some of our authorities claimed longer wear-life for the white irons than for gray irons, but actual working conditions have not demonstrated that this is a fact. Some white irons have given wonderful wear; then, again, there was a great difference in wear-life to castings from the same run of metal. The same is true of gray irons. We begin to see, however, as machines become more bulky and as weights on wearing surfaces become greater and the speeds are increased, that neither of the two types of iron on which we have depended so long will much longer answer our purpose.

We know, of course, that nickel strengthens cast iron, gives it a finer structure, and because it must be tapped hot, it is more fluid and makes fewer scrap castings than are found in most gray iron foundries. It also enables an iron to be machined that ordinarily chills too hard for cutting.

We also know that chromium adds hardness and reduces machinability unless it is kept to about half the amount of nickel. This combination gives physical qualities that cannot be found in the straight nickel cast iron.

As to wear resistance of nickel irons, we find a great divergence of thought. I believe, however, that the automobile manufacturers have been slowly turning to a nickel content iron for motor blocks, and at least one manufacturer has gone to both nickel and chromium for both strength and wear, yet holding machinability on a par with gray iron. Another factor is less scrap.

Now to return to our own experiences: As a result of testing and as scrap from manufacture, quite a supply of nickel-chromium-copper cast iron with total carbon between 2.6 and 3.0% was collected. Because of its fine texture, it was decided to use it in a test casting for a machine part that had shown woeful lack of resistance to frictional wear. It gave very surprising results in a wear-life nearly triple that of any iron used before. Two more tests gave the same results. It was felt that three tests were sufficient to prove the point.

It was then decided to follow the tests in another direction, and make a cylinder block and test the resistance of this iron to wear under the conditions imposed in the automobile. A six-cylinder block was accordingly installed in one of our cheapest automobiles in the latter part of 1927. The cylinders were carefully honed to obtain a smooth surface, and the rings and pistons carefully fitted and assembled. Our experience indicated that the block in a stock car would need reconditioning every 10,000 miles.

At 3,000 miles the cylinders were examined and there were still a few of the hone marks visible on the sides of the bores, laterally. At 9,000 miles they had been entirely obliterated. At 13,000 the rings were changed, as they showed wear and had lost most of their tension. At 18,000 miles, the bores were carefully gaged. They did not show 0.0005 in. wear laterally and the wear on the medial line could not be detected. The surface of the bore was like glass with no indication of scratches of particles of carbon, that are often seen, nor were there any pits or gouge marks. The block has not been examined since then, as the wear of the bore seemed to indicate a wear-life of about 100,000 miles before the cylinders would need honing.

Some years back a firm was advised to use this metal in a position where great wear showed on all of their machines, but the suggestion was turned down by the chief engineer. He said, "Copper in cast iron makes the iron rotten and porous. Nickel and chromium may be all right, but copper, never! The only thing that I can say against a nickel-chromium alloy is its great added cost." And this expression seems to characterize the thought of all men to whom the question is put.

One final remark: Addition of aluminum to the mixture seems to add to the corrosive qualities and subtracts from the wearing qualities. It also produces a more open grain.

C. G. WILLIAMS

COOPERATIVE RESEARCH

at Battelle

Memorial Institute

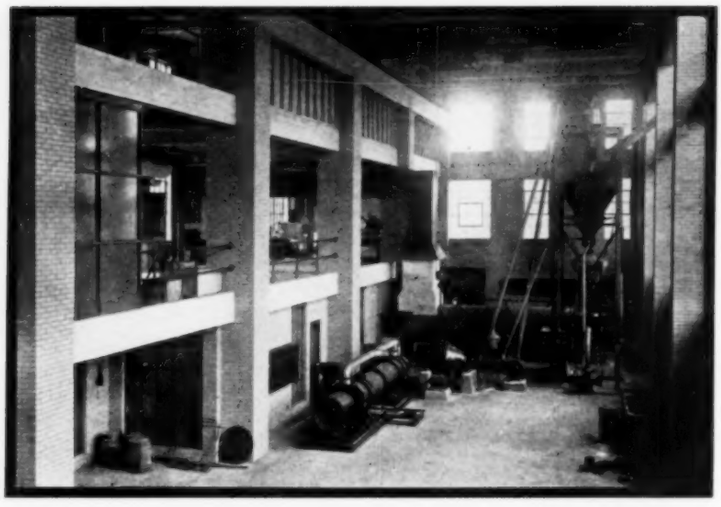
IT IS not so many years since new and improved processes and products were the result of accidental discoveries or of independent work by some person of inquiring mind and vague theories. Now, however, the need for organized research is fully realized, and more and more provisions are being made for this type of work, both by industrial concerns and by scientific organizations. Large manufacturing organizations or groups are devoting great sums to research and development work and independent industrial laboratories are continually widening their fields of research. Valuable work is being done in the various Government bureaus and experiment stations, and in university and engineering school laboratories.

One of the newest research organizations is Battelle Memorial Institute in Columbus, Ohio, which has been actively engaged in research since July, 1929. This is a privately endowed laboratory, so organized as to have several unique advantages. It is run on a non-profit basis in such a way that research can be made for industrial concerns at moderate cost. Furthermore, it is not hampered by the routine testing which must be carried on by industrial laboratories, nor by the obligation to make all of its work public property, as must the Governmental laboratories.

Battelle Memorial Institute was founded by Gordon Battelle as a memorial to the family name. It is dedicated to research in metallurgy and fuels, fields in which the Battelle family had long played a prominent part in the industries of Ohio.

The building stands in a residential district of Columbus, near Ohio State University. It is approximately 160x200 ft., 3½ stories high, and has 90,000 sq.ft. of available floor area. The grounds cover 3½ acres, providing space for the erection of auxiliary structures, the first of which was completed in March, 1931, and is a 40x80-ft. building for sample preparation and storage.

The original staff, numbering about half a dozen in July, 1929, has grown to 75 members, most of whom are engaged in actual research work. Forty college degrees from 25 institutions in all parts of the country are represented and the researchers are all men of recognized standing in their particular fields. Since the Institute is able to accommodate a much larger staff and contains much working space not yet used, this rate of growth can be continued for several years to come.



Laboratory for Work on Semi-Plant Scale. Other equipment has been added

There are at present 25 projects under investigation, about half sponsored by industry and the other half undertaken by the Institute itself or in cooperation with other technical institutions. Research projects are being added at the rate of one a month. The activities of the Institute are under the directorship of H. W. Gillette, with O. E. Harder and C. E. Williams as assistant directors.

Full equipment and facilities for almost any type of metallurgical or fuel problem are already provided or can easily be obtained. Each problem undertaken by the Institute is divided into four phases; preparatory, laboratory experimental, development, and semi-plant scale operation. This plan may be varied according to the nature of the problem, but in all cases a complete preliminary study is made and a definite experimental program outlined. Monthly progress reports are required on all projects.

Cooperation With Industry

Those researches which are undertaken for industrial firms are organized under the "Sponsored Research Plan." The firm standing as sponsor pays the salary of the research engineer in charge of the project and provides funds for materials and operating expenses, none of which are diverted by the Institute as a profit. Adequate equipment and supervisory personnel are provided by the Institute, but the results of the sponsored research project are the full property of the sponsor.

A typical sponsored research project has been under way on the properties of cast iron. The sponsor of this work was the Worthington Pump & Machinery Corp. and the object was to investigate the three types of cast iron used in the manufacture of its products. Extensive microscopic, tensile, fatigue, wear, and long-time, high-temperature creep tests are being continued on ordinary iron, high strength iron, and alloy cast iron.

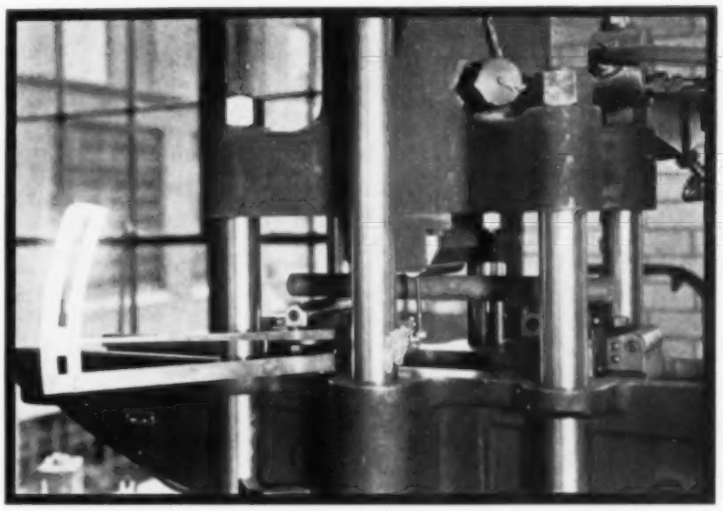
A study of the embrittlement of structural steel by hot galvanizing is sponsored by the Utilities Research Commission of Chicago and the American Society for Testing Materials. Large structural angles are pickled and galvanized at a local plant interested in the project and tested at the University where an adequate testing machine is available.

Another extensive research is sponsored by two steel companies and two ore producers. This is the study of improved concentration methods for low grade iron ore of the Lake Superior region. A great deal of space at the Institute has been appropriated by concentration, flotation, and magnetic equipment for this project, part of which was designed and built in the Battelle laboratory's shops.

The Institute is also conducting sponsored research on lubricants for wire drawing, for which a wire-drawing machine has been constructed; another on insulation; and still another on sand used for casting (its fusibility and the recovery of used sands).

Of the researches supported by Institute funds, one of the most interesting is on the combustion of pulverized coal. The apparatus for this is erected in the industrial laboratory (a large room, three stories high, reserved for heavy and semi-plant scale equipment).

An outstanding example of cooperation with other scientific institutions is the work on Alloys of Iron Research. This was originated by the Engineering Foundation under an



Amsler Machine in the Testing Laboratory Set Up for a Transverse Test

appropriation of about $250,000 supplied by industries, technical organizations, and institutions, the research to be continued over a period of five years. The actual work is divided among Battelle Institute, Carnegie Institute of Technology, Lehigh University, Bureau of Standards, and the Engineering Foundation in New York. That part of the problem being studied at Battelle consists in the correlation into three monographs of the existing literature on iron-carbon, iron-molybdenum, and iron-tungsten alloys. The iron-molybdenum monograph is now in draft form.

Another cooperative research is on the White Process for the coking of coal, which is being carried on jointly with the Engineering Experiment Station at Ohio State University.

A study of the effect of ash and slags on refractories for boiler furnaces is being made for the American Society of Mechanical Engineers. This work necessitated the construction of a small constant-temperature furnace in one of the laboratories.

Most of the work is conducted in individual laboratories in the front part of the second and third floors. These range in size from 12x22 to 24x22 ft., while one is 75x32 ft. They are roomy, well-lighted and ventilated, and contain desks, tables, chairs, cases, a hooded cabinet, and a wardrobe as standard equipment, with facilities for the installation of any necessary special equipment. All laboratories are supplied with alternating, direct, and battery current, hot, cold, and distilled water, and with gas, steam, vacuum, and compressed air lines. A section of the third floor above the industrial laboratory is not yet partitioned into laboratories, but is reserved for future expansion.

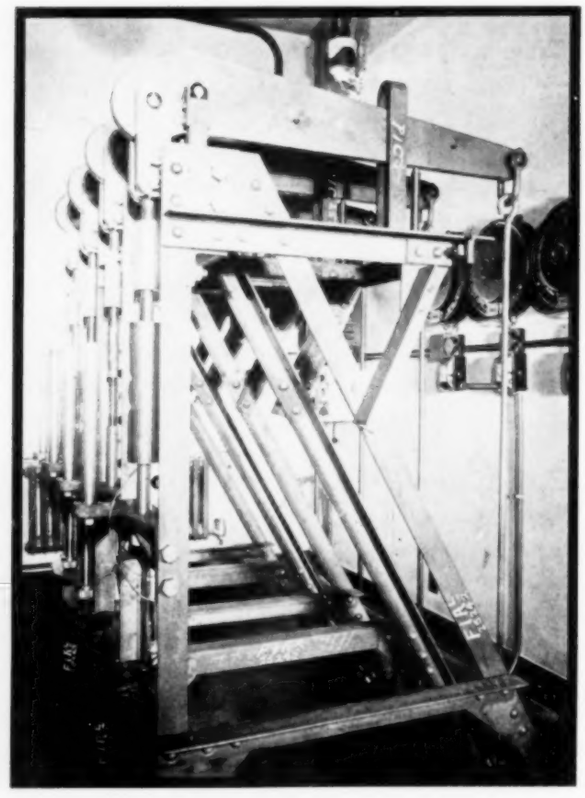
Physical, chemical, microscopic, and industrial laboratories are provided for general use. The industrial laboratory, 130x30x36 ft., contains a rolling mill, forging hammer and billet heating furnace as well as the coal-pulverizing equipment mentioned above and a small foundry for experimental casting. It is served by a 5-ton overhead traveling crane. Other heavy equipment is housed on first and second-floor bal-

conies on two sides of this laboratory. One section contains six electric and gas-fired furnaces of different types for heat treating, all supplied with recording and controlling pyrometers. A mechanical testing department is furnished with two precision tensile testing machines, four R. R. Moore fatigue testing machines, one equipped to operate at —40° F., an Amsler wear testing machine, and an Amsler universal impact machine.

The physical laboratory contains equipment for electrical, thermal, and pyrometric measurements, and an X-ray machine. Service work is done in the chemical laboratory for those researches involving chemical analysis, as well as original research in metallurgical analysis. The metallographic laboratory is fully equipped with modern automatic polishing machines, microscopes, and photographic apparatus.

A carpenter shop and a machine shop for constructing apparatus and preparing test specimens are in the basement, which also contains a book bindery, storeroom and constant temperature vault for precision work.

Long-Time, High-Temperature Creep Testing Apparatus for Cast Iron



One of the most important divisions of the Institute is its library, for adequate knowledge of the literature is one of the essential requisites of any research problem, and this preparation must be obtained largely in the library. It occupies three fine rooms in the west end of the main floor. One contains current periodicals, another general reference books, and the third bound volumes of periodicals. A unique feature of this library is its card index, containing over 100,000 card references to current metallurgical subjects arranged under subject, author, and title. Abstracts of articles on metallurgy, fuels, and allied subjects are clipped from current abstract journals (which are obtained in triplicate by the library) and pasted on the cards; complete bibliographies on any subject in these fields are therefore easily accessible.

A method of evaluating current literature is provided by pasting a slip on the cover of each periodical. Then, as one of the staff reads something particularly interesting, he notes the page on the slip and the article is abstracted and indexed. The men are further served by a "Current Literature Review," a mimeographed list of references to periodical literature prepared each week by the librarian and distributed to every member of the staff. The library receives 140 current periodicals and contains over 2,000 volumes which are being constantly augmented.

In the opinion of the Director, the Institute's ideal of "application of science to industry" can best be carried out through cooperation, not only within the staff, but also between the Institute and other technical organizations for the mutual benefit of all. It has been shown in this brief account how this is realized in the joint projects with the Engineering Foundation, the A.S.M.E., and Ohio State University. In the last-mentioned, the two organizations cooperate not only in investigative work but also in library facilities, duplication being avoided as far as possible.

In its equipment, personnel, and ideals, Battelle Memorial Institute is a shining example of faith in the motto over its portal: "Original Research Is Mankind's Most Powerful Weapon in Solving the Problems of Nature."

CONCENTRATES

from current literature

"OLD Charcoal Blast Furnaces of Kentucky," as described by Ralph H. Sweetser in October *Mining and Metallurgy*, p. 450, brings back to mind an important industry of the middle 19th century, now vanished. Remembering the changes which time has wrought in the lines of iron blast furnaces, and the slow extinction of the blast furnace in copper smelters, Mr. Sweetser is not so sure that the present mammoths making 1,500 tons of pig a day represent the eventual and permanent goal of the industry.

Among future changes may be the dry blast, and those who like to speculate will enjoy William McConnachie's article, "Rationale of a Dry Blast in Iron Smelting," in *Blast Furnace and Steel Plant*, October, p. 1,341, wherein he attempts to explain the causes for a reported 80% fuel saving by a consideration of the various reactions in the stack. He concludes that much more carbon is deposited on the unreduced ore by dry gas, and this is the active reducing agent. Some extensive tests have led foundrymen to believe that dry blast iron would have definite advantages for machinable gray iron castings.

FURTHER insight into the rational manufacture of clean open-hearth steel is given by a series of reports to the Metallurgical Advisory Board, Carnegie Institute of Technology, Pittsburgh, Oct. 16, by C. H. Herty, Jr., and his associates. Studies on the solubility of various oxides in molten steel, and the development of rapid and accurate analytical methods for solid inclusions, have enabled these men to analyze a number of furnace heats and to develop a furnace practice whereby the refining and casting of a heat, after the first addition of spiegel, is done by clock. Investigation of slag systems MnO-Al_2O_3-SiO_2 and CaO-SiO_2-Al_2O_3 has discovered certain "families" of analyses giving quite low melting points. Metallic alloys (silico-manganese, "alsifer," and Ca-Al-Si) of correct analysis to give such low melting slags after oxidation have been tried on commercial heats, and indicate large possibilities in the production of clean steel, since the liquid slag particles from the reduction of iron oxide in the steel readily coalesce and rise to the surface.

DATA on the influence of copper in steel are contained in a pair of articles in *The Iron Age* (Sept. 10 and 24) by H. B. Kinnear entitled "One Per Cent Copper Steel." Steel foundry practice since 1925 indicates that this amount of alloy has this characteristic effect on heat treatment: A normalized specimen will have its strength and yield point increased about 19,000 lb. per sq.in. after reheating to 1,000° F. The phenomenon is probably due to precipitation of copper from solution in ferrite during this tempering. High strength castings (replacing several other analyses) are now made with C 0.28 to 0.34, Mn 0.60 to 0.75, Si 0.35 to 0.45, and Cu 0.90 to 1.0%. Physical properties in the normalized and reheated condition are 73,000 to 77,000 lb. per sq.in. yield, 95,000 to 103,000 lb. per sq.in. ultimate, 21 to 24% elongation in 2 in., 42 to 50% reduction, and 187 to 217 Brinell. Forging tests on large ingots indicate that this alloy can easily be rolled, and the physical properties materially improved.

In contrast with these recent results, Sir Robert Hadfield presented a voluminous account of Michael Faraday's metallurgical

studies to the British Association for the Advancement of Science. A box of 79 small specimens, boxed and labeled by Faraday's hand, has been in the storeroom of the Royal Institution for over a century. These were sampled, analyzed, and some properties determined. Some of the alloys were put into commercial production at Sheffield for cutlery and other articles, but the young experimenter apparently received so little encouragement that he turned his attention to investigations on magnetism and electricity. Here rests his fame.

"Effect of Molybdenum on Medium Carbon Steels Containing 1 to 2.5% of Manganese" was reported to the September meeting of the British Iron & Steel Institute by G. Burns. Definite test results are given to verify the general understanding that 0.3 to 0.5% Mo will increase the depth of hardening and improve the impact value and strength of medium manganese steels, quenched and tempered. The upper limit of molybdenum "almost eliminates the susceptibility to temper brittleness."

BRIGHT annealing on a large scale is done in a modernized strip mill of American Steel & Wire Co. in the Cleveland district *(The Iron Age,* Oct. 13, p. 1,000). A stack of coils is covered with a 16-gage cylindrical shell of 18-8, which has a well down its axis extending into the open center of the coils. This shell rests in a seal on the base, and remains throughout the entire heating and cooling cycle, since it imprisons the neutral atmosphere (a coke oven gas, cleaned of oxygen, water, and sulphur). A brick-lined steel cover, or furnace, is then lowered over the shell. This cover has resistor elements on its inside surface, and also on a central pole which extends into the well of the 18-8 shell, to radiate heat into the coils both from outside and inside. Heating a 2½ to 6-ton charge to 1,300° F. requires 6 to 10 hr. The furnace then is moved to a second loaded base; the hot coils and protecting shell require 24 to 32 hr. to cool to non-tarnishing heat.

According to W. H. Cunningham and J. S. Ashbury, in a paper read before the September meeting of the British Iron & Steel Institute, workshop methods used by Thomas Firth-John Brown, Ltd., for nitriding small articles in two-ton lots, include cleanliness of articles (oil and scale-free) as a prime essential. Method of packing is also important — nickel grids and wires are used for separators. Dead soft areas are insured by a layer of solder (Pb:Sn 80:20); moderate softness by painting with aluminum powder suspended in sodium silicate. Causes of distortion are discussed and average figures for growth are presented. Soft, crumbly areas are nearly always due to metal decarburized during some former operation; dull slate-blue coloration on brittle cases is caused principally by air leaking into the container.

COBALT steel tools, in the opinion of J. M. Highducheck *(American Machinist,* Sept. 17, p. 450), represent a stage in development midway between high speed steel and cemented carbides, and he cites tests to prove the point. A chart showing the standard forged tool shapes used by lathes, shapers, planers, and boring mills in Westinghouse plants is printed, together with hints on the brazing of tips into carbon steel shanks, for economy. He emphasizes that cobalt steel should be tempered immediately after quenching, and held at least one hour at a temperature of 800° F.

Precautions to be used when grinding cobalt steel tools are also listed. Grinding cracks are well-known causes of rejects, and have frequently been described in a qualitative way. C. E. Sweetser, in *Steel,* Sept. 24, p. 31, gives definite data as to wheels, speeds, and feeds which will and which will not crack given tool steels. His article, "Abusive Heat Treating or Grinding" presents evidence that air-hardening (high carbon, high chromium) steels are less susceptible to cracking than high speed or oil-hardening tungsten-chromium steels.

PRESS work, tool and fixture design, and the limit of cold work before annealing are subjects discussed at length in two series of articles. One, by H. C. Lane in *The Engineer* (London), pays most attention to the mechanism of the shop operation. The second, by E. V. Crane in *The Iron Age,* describes the metallurgical characteristics of the sheet or strip in process. In the issue of Oct. 1, p. 872, for instance, the latter author shows how the temperature of recrystallization, and the rate and uniformity of plastic working affect operations on nickel and brass.

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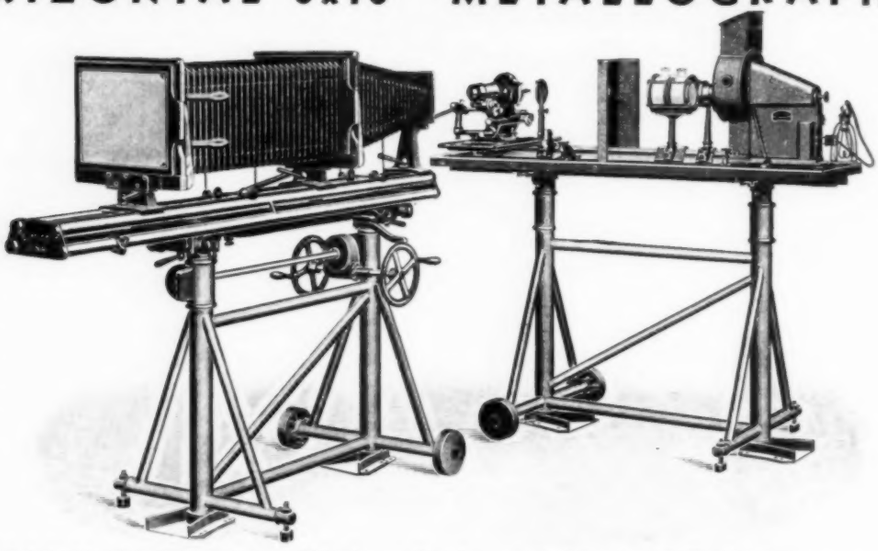

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Before me, a notary public, in and for the State and county aforesaid, personally appeared H. Kenneth Briggs, who, having been duly sworn according to law, deposes and says that he is the assistant business manager of METAL PROGRESS, and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management, etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, embodied in section 411, postal laws and regulations, to wit:

1. That the names and addresses of the publisher, editor, managing editor, and business managers are: Publisher, American Society for Steel Treating, 7016 Euclid Avenue, Cleveland, Ohio; Editor and Managing Editor, Ernest E. Thum, 7016 Euclid Avenue, Cleveland, Ohio; Business Managers, W. H. Eisenman, 7016 Euclid Avenue, Cleveland, Ohio, and H. Kenneth Briggs (assistant), 7016 Euclid Avenue, Cleveland, Ohio.

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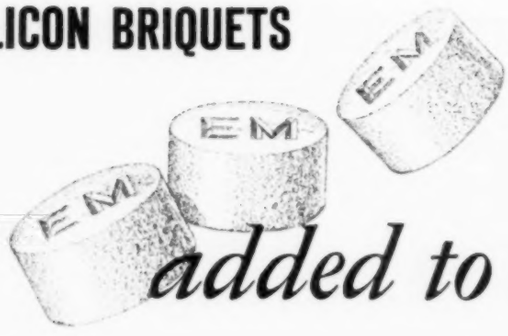
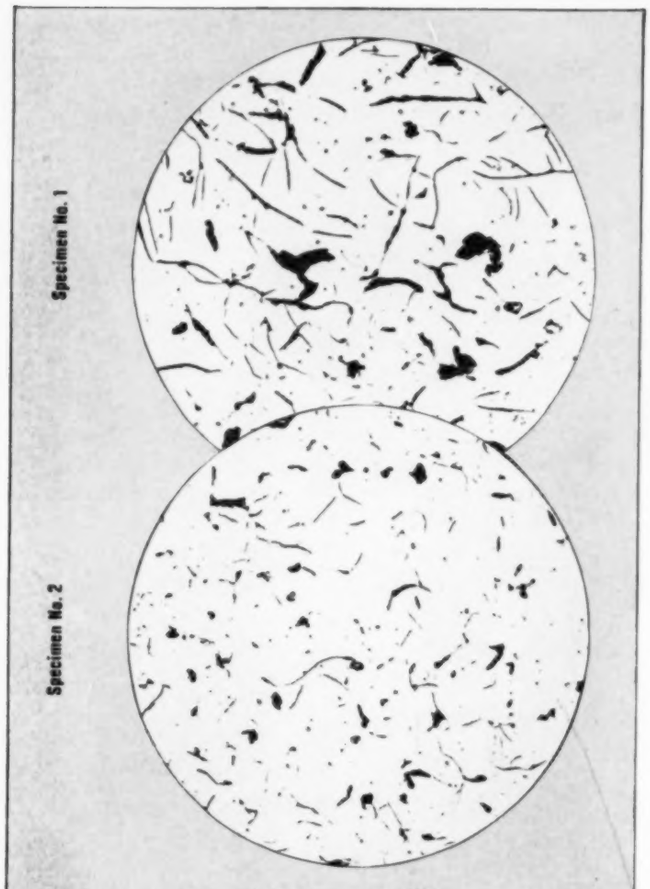


added to the cupola



ANALYSIS

	Silicon	Total Carbon	Manganese	Sulphur
Specimen No. 1	2.30%	3.25%	0.69%	0.106%
Specimen No. 2	2.15%	3.00%	0.69%	0.105%

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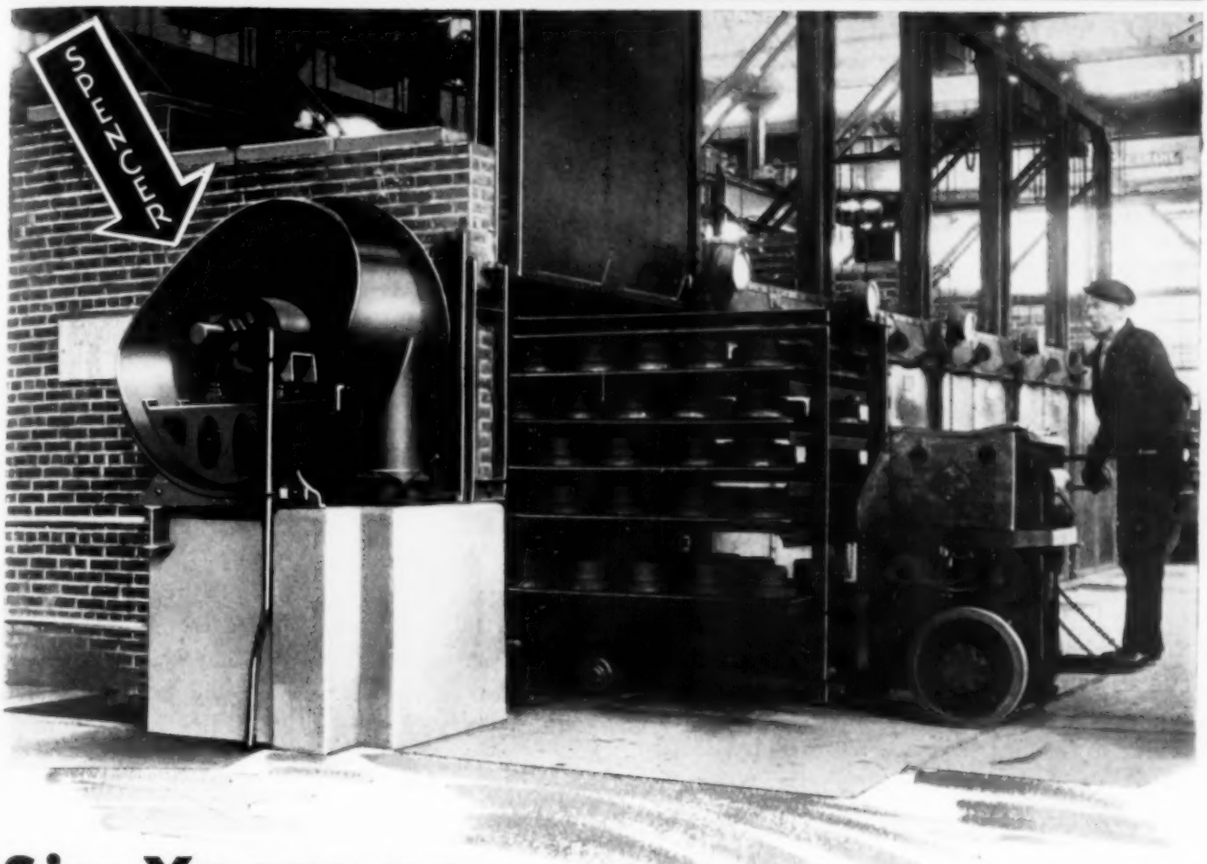

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ANCIENT IRON

Several roakes run in from the base, into which oxidizing agents have worked, causing rusting to perhaps twice the original width.

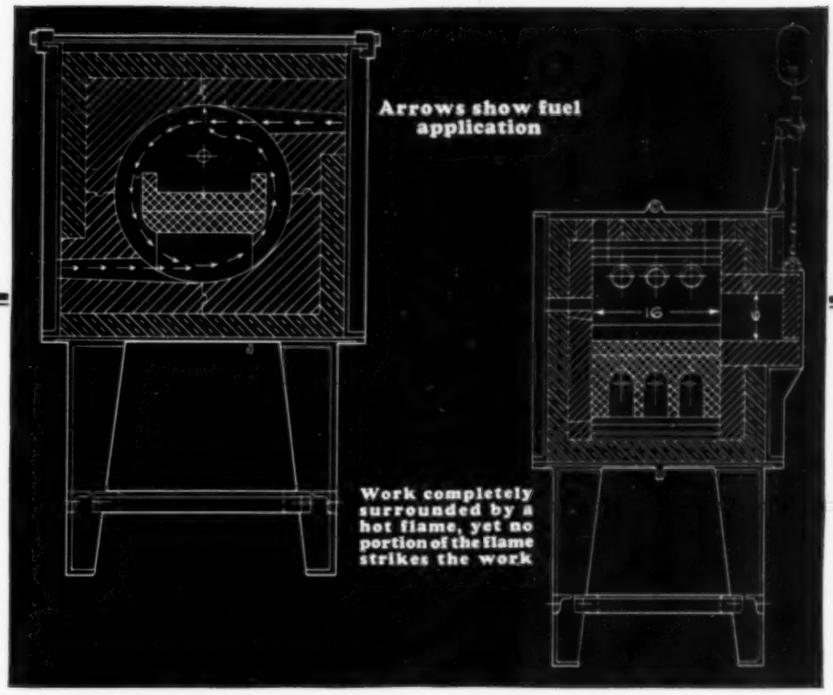
To produce such a series of changes of structure, end to end, it would seem that a flat bar (itself a laminated steel) has been heated to a white heat at one end and then gripped in heavy tongs or vise and upset to produce the lower flange. The other end was then heated to a white heat and similarly upset into a flange now missing. Heat naturally lowered toward the middle of the bar, and at d it reached about 1,650° F., while at the lower part of piece 5 it did not reach a cherry red.

In the simpler types of Greek bar clamps the heads were formed merely by bending in one direction or another; it is obvious that a higher technique is required for the clamps under examination. One might suppose from a cursory examination of the shape that separate heads might have been welded to the shank, although this would be a difficult feat on an anvil — easy for a welder with oxy-acetylene flame. Possibly the ends of the shank were split and folded apart, being then strengthened by welding to an additional plate. Even this was unnecessary. It is evident that the heads are integral parts of the shank and were shaped by reheating and upsetting; apparently, only the central part of the original bar was first worked into the dimensions required for the shank, the more massive ends being then successively reheated and hammered back against the side of the vise which gripped the end of the shank. In specimen W-170, as shown in the photograph on page 45, the edge of the head projects very slightly beyond the edge of the shank, implying that when it was upset the head, as was natural, spread out in all directions and was afterwards trimmed off to fit the shank.

W-170 Between f_2 and f_3 at 500 Diameters Shows the Hardened Structure

Such a manufacturing procedure could originate with a lump of iron direct from the forge in which it was smelted. Even up to recent years the practice at bloomeries was to take out the "loup" or bloom of iron and forge it in the middle to the dimensions of the finished bar, leaving both ends unforged. It was then called an ancony by English, or encrénée by French workmen. After reheating the ends would be hammered down to shape. Perhaps the ancient workmen merely upset the ends of what was Greek for "ancony."

One cannot argue that the pieces were composite — that is, welded from several bars from several sources — merely because the microstructure shows such wide variations. It must be remembered that the metal coming from hearths which produced forgeable iron direct from the ore is quite irregular, not only heat to heat, but from point to point within a single heat. Analyses of the bar "iron" which was the staple material of construction prior to Bessemer's invention (less than a century ago) showed carbon to range from a trace to 0.25%. Quoting W. H. Greenwood's remarks On the Production of Malleable Iron Direct From the Ore in "Steel and Iron," a widely used college text-book a generation back: "The product is only an agglomerated mass of wrought iron or steel, or, more correctly speaking, is always a mixture of soft with steely iron in variable proportions, the preponderance of the one or the other quality depending largely upon the rapidity of reduction — if quick, only a short exposure of the reduced metal to the recarburizing influence of the fuel is afforded and soft iron will accordingly predominate in the yield." In this passage he is speaking more particularly of iron from the Catalan forge, which, while antique to us, is doubtless an improvement on the equipment used 2,000 years ago, even though it operates in the same way on the same raw materials — namely, a gentle blast of air blowing into a mixture of iron ore and charcoal.



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REVIEW OF PATENTS

of interest

to metal men

by Nelson Littell
Patent Attorney
22 E. 40th St.
New York City
Member of A.S.S.T.

Wrought Iron, *by Addison H. Beale and James Aston, Pittsburgh, assignors to A. M. Byers Co. 1,820,176; Aug. 25.*

In the Aston process for making wrought iron, the molten product of the steel making process is poured into a slag bath and granulated by reason of the temperature difference between the bath of slag and the steel poured in. It has since been found that the depth of the slag bath should be controlled as well as the temperature, and that it is also necessary to control the weight of the slag, the height of the falling stream and the time consumed for the shotting of a given weight of material. The shotting cup is an iron or steel shell which converges downwards to a slight extent on two sides and to a greater extent on the other two sides. Suitable trunnions are provided and the casting is preferably provided with a projecting flange and is lined with a refractory material such as firebrick, covering the bottom and sides. The internal dimensions of the lined vessel are about as follows: at the bottom, 3 feet between the sides bb and 4 feet between the sides aa, with a depth of about 4½ to 5 feet. The liquid slag is poured in preferably to a depth of 4 feet and the liquid steel is poured in from a height of 6 feet to 12 feet. The pour is regulated so that the pouring rate is not faster than 1½ tons per minute and the volume of slag is more than four times the volume of metal poured into said slag. With such operation the quality will be more uniform.

Quenching Tank, *by Frank T. Cope, Salem, Ohio, assignor to the Electric Furnace Co. 1,808,160; June 2.*

This apparatus is for quenching articles emerging from a heat treating furnace and more particularly for cooling and circulating the quenching fluid. The tank is adapted to contain oil or other quenching fluid and is provided with baffle walls and a propeller for continuously circulating the fluid through the tank a predetermined path. An endless chain belt is provided in the tank and extends upward out of the discharge end for conveying articles or materials to be quenched through the quenching fluid and discharging the same therefrom. The propeller circulates the liquid in the direction of movement of the articles.

(Continued on Page 104)

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That Very Trying Affair at Boston

(A short, short, true* mystery story)

By *One Who Now Knows Better*

"MR. ADAMS, of your research department, please," requested the visitor as he presented his card through the window at the reception desk. Deft fingers promptly plugged in the necessary connection.

"Mr. Adams will see you in just a few minutes," came in mellow and obliging tones from the golden-haired director of the switchboard, "won't you be seated?"

Yes, he would be seated, and then, in just a few minutes, he hoped, be directed to the research department. Just where he wanted to get to! For despite the storm which raged outside and through which he had sloshed through in his car for several miles to the outskirts of Boston, this instrument sales engineer, it must be said, was still optimistic over the outcome of his mission, his spirits had so far resisted the depressing effects of a dismal day. "This is the time I find out," he had told himself as he slammed the door of his car with a decisive bang and sprinted through the pelting rain to the factory office of a company whose household product is known throughout the world. He had about convinced himself for the second time that he would be successful when he heard a familiar voice.

"'Lo, Kent. Didn't suppose you'd come way out here in a 'north-easter' like this one. Must be something very important to bring you out here on a day like this," smiled Adams as he shook hands with the visitor who had not heard Adams approach. Later on, the sales engineer had occasion to remind himself that some research men make as little noise in moving around as they do about what they're working on. Adams was a soft-spoken man, of slim build, about thirty-five, his clear-cut features marked by a pair of clear, blue, penetrating eyes.

Before Kent had a chance to speak Adams went on. "Everything's working properly, the SO_2 installation on our stack's working satisfactorily showing us a nice saving on fuel. The thermo-couples have just come back from your factory after being annealed, so, you see, everything's just as it should be."

Everything might be as it should be, thought Kent, but so far as he was concerned that wasn't altogether so. Was Adams going to continue to stand or was he going to invite this sales engineer upstairs?

"How's the new instrument working out up in your department?" ventured Kent hopefully.

"Fine," replied Adams seating himself on the settee and motioning Kent to do likewise, "fine, a very fine and useful instrument. Wouldn't like to be without it." Kent had seated himself reluctantly, far away from the research department upstairs.

"Glad to hear that, Mr. Adams, but just how are you using it," persisted Kent, "just what are you doing with it?" Adams got up from the settee. Kent sprang up expectantly. But Adams moved over to the window, away from the stairs.

Kent's shoulders drooped, but when he observed the smile playing about the corners of Adams' mouth, they quickly resumed their normal position, even though Kent did not observe also the little twinkle in those clear blue, penetrating eyes, as they gazed out the window at the raging storm.

"It's quite a storm we're having. Makes a very depressing afternoon of it, doesn't it?"

Kent's spirits had now almost touched bottom but not quite. "Certainly does," he replied making an almost futile effort to smile. "Won't you give me even a clue?" he still persisted.

"Sorry," smiled the research engineer turning away from the window, "it's against the policy of the Company to permit my department to give out any information about its activities. But the 'Gasalyser' is a very fine instrument. Very sensitive. Does all you claim for it. And when a research man is concerned with problems involving gas analysis or efficiency of combustion, the 'Gasalyser' becomes a valuable instrument, and at the new low price an investment well worth the money. But as to just what we're doing with the 'Gasalyser' I can't give you even a clue. Sorry."

Another mystery and not even a clue! And not much use trying to get a clue. It would be just another trying affair. But, come to think of it, you can't expect these research men to tell you much about what they're doing. But, like Adams, they'll admit they like the "Gasalyser."

So we look forward to a good many more mysteries where we can't get even a clue. And, incidentally, any mystery regarding the principle on which the "Gasalyser" operates, and its new low price, can be solved by addressing CHARLES ENGELHARD, INC., 233 N. J. R. R. AVENUE, NEWARK, NEW JERSEY.

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Copper Brazing—Process Engineering & Equipment Corp. Leaflet on special electric furnaces for copper brazing sheet steel stampings, steel and cast iron, pressure tight joints, water tight floats, etc. Bulletin N-81.

Heat and Corrosion Resistant Alloys—Michigan Steel Casting Co. A 16-page bulletin describing and illustrating various cast, rolled and fabricated alloy structures for use at high temperatures. Bulletin N-12.

Globar Elements and Accessories—Globar Corp. A new leaflet containing a list of standard industrial type Globar electric heating elements and a coordinated list of terminal mountings and accessories. Bulletin N-25.

Furnace Parts—Driver-Harris Co. has issued a bulletin featuring furnace parts made of their alloys. This bulletin gives data and advantages of Nichrome and Chromax heat resisting alloys in the form of furnace parts. Bulletin N-19.

Automatic Metallographic Polishing Machines—E. Leitz., Inc. Catalog illustrating and describing the Guthrie-Leitz automatic polishing machines of the one, two and four-spindle types. The new Leitz specimen clamps are also described. Bulletin N-47.

"The Path to Permanence" is a newly revised booklet on Toncan copper-molybdenum iron issued by the Republic Steel Corp. It contains 64 pages of interesting installation and metallurgical data on this rust resisting sheet metal. Bulletin N-8.

Ni-Resist Bulletin—International Nickel Co. The physical, chemical and mechanical properties of this nickel-copper, chromium cast iron are presented with a discussion of its practical utility and the findings of independent investigators. Bulletin N-45.

Welded Construction Folder—Bethlehem Steel Co. Folder describing the use of rolled steel shapes and plates for the building of machinery parts by welding. The results are said to be sturdier construction, reduced weight, low cost, and elimination of patterns. Bulletin N-76.

Case Hardening—Roessler & Hasslacher Chemical Co. New 80-page booklet on case hardening, nitriding, reheating and mottling of steels with R & H cyanides. Also coloring, tempering, drawing and annealing of steels with R & H salts. Helpful charts, tables and methods of analysis included. Bulletin N-29.

Multiple-Purpose Furnace—Leeds & Northrup Co. The new L & N "Ho-Hump" multiple purpose furnace does Hump hardening, Homo tempering and Homo nitriding. Useful in small shops or for regular production of hardening or tempering plus experiments or regular production in nitriding. Description by requesting Bulletin N-46.

Modern Industrial Furnaces—Surface Combustion Corp. Booklet covering the research, development and engineering activities of the Surface Combustion Corp., and their application and the advantages obtained by S-C furnace users as a result of these factors. Bulletin N-51.

Cold Finished Bar Bulletin—Joseph T. Ryerson & Sons, Inc. Bulletin describing the wide variety of shafting, screw stock, and open-hearth case carburizing steels in use today. A range of products is given, a list of standard tolerances and S. A. E. specifications. Bulletin O-50.

Industrial Gas Heat—American Gas Association. A veritable textbook on the uses of gas heat in industry, profusely illustrated with photographs of installations, etc. Bulletin A-10.

Aluminum Welding—Aluminum Company of America. Instruction card to be hung in the shop for ready reference, giving directions for welding aluminum. Bulletin A-54.

Hacksaw-Ology—Simonds Saw and Steel Co. Book illustrating and describing the uses of hacksaws. Bulletin JJ-69.

Industrial Application of the X-Ray—General Electric X-Ray Corp. Booklet gives many examples of the use of the X-Ray in the industrial field. Profusely illustrated with radiographs of castings, welds, assemblies, etc. Bulletin M-6.

Trade Pamphlets Continued

Production Carburizing—American Gas Furnace Co. Bulletin describing the purpose, principles involved, types of machines used and how they are constructed for production carburizing, also nitriding, bright annealing, hardening, annealing and tempering. Bulletin A-11.

Steel Users Reference Book—William Jessop & Sons, Inc., issue a booklet showing compositions, thermal treatment, mechanical properties and uses of various types of tool and constructional steels. The theories of hardening are discussed in their practical aspects. Bulletin M-61.

Fatigue Testing Machine—Thompson Grinder Co. Interesting data on fatigue testing and description of the rotating beam type of fatigue testing machine are given in Bulletin M-23.

High Test Welding Rod—The Linde Air Products Co. A 12-page booklet describing the qualities and advantages of high test welding rod. Extensively used for fabrication of pipe lines, pressure vessels or other welding operations where high strength and economy are required. Bulletin JJ-63.

Ferro Alloys and Metals (Third Edition)—Electro Metallurgical Sales Corp. Describes current practices with specific reference to the "Electromet" products supplied to the metallurgical industry by this organization, together with suggestions for their use in both the ferrous and non-ferrous industries. Bulletin JJ-16.

Ingot Molds—Gathmann Engineering Co. The subject of ingot molding is covered in a new book on this subject. Numerous illustrations of the effect of various methods of finishing and casting on the reliability of steel products are given. Bulletin S-13.

Furnaces for the Steel Industry—The Electric Furnace Co. have issued a four-page folder illustrating and listing several electric and fuel fired furnaces of various types they have installed in steel plants. Bulletin S-30.

The Coreless Induction Furnace in the Steel Industry—Ajax Electrothermic Corp. Reprint of a paper describing recent developments in high frequency coreless induction furnaces and their probable applications. Bulletin S-41.

Electric Steam Generators—General Electric Co. Booklet describing and illustrating G. E. electric steam generators for process work. A list of applications is included showing how these generators may be used in a wide variety of industries. Bulletin S-60.

Electric Heat Treating Furnaces—Ajax Electric Co., Inc. Photographic description of new electric furnaces for annealing wrought products, such as sheet, wire, tubing, rod, etc. Bulletin S-83.

Recorder Controller—Bristol Co. Catalog describing and illustrating Bristol's air-operated free vane recorder controller. Bulletin O-56.

Aluminum Alloy Castings—British Aluminium Co., Ltd. Booklet contains information on aluminum alloys used in all manner of light alloy castings. Contains a quantity of technical information for foundries and users of aluminum alloys and alloy castings. Bulletin O-78.

Potentiometer Pyrometer—The Brown Instrument Co. 16-page booklet explaining and illustrating the principal feature of the new Brown potentiometer pyrometer with special reference to accuracy of operation and ruggedness in service. Bulletin N-3.

Oil and Gas Burners—W. S. Rockwell Co. Bulletin illustrating and describing various oil and gas burners for industrial heating furnaces. Bulletin N-49.

Refractories—E. J. Lavino & Co. Literature on Kromepatch and Plastic K-N chrome ore refractories for industrial furnaces. Bulletin O-40.

"Carbonal Process for Carburizing Steels" is the title of the new 12-page bulletin published by the Hevi-Duty Electric Co. The bulletin describes the results and advantages of the Carbonal process of carburizing. Bulletin N-44.

Furnaces—George J. Hagan Co., industrial furnace builders, have recently issued several new descriptive booklets describing their furnaces. Copies are available by requesting bulletin M-42.

Large Metallographic Microscope—Carl Zeiss, Inc. A 28-page illustrated booklet describing the working arrangement of this instrument as applied to the field of metallography. Bulletin 397.

Practical Metallurgy for Engineers—E. F. Houghton and Co., Philadelphia. A 435-page book by the Houghton Research Staff, covering practical metallurgy in all its phases. Copies of the third edition are obtainable by sending $3.00 directly to the above company.

Gasalyser—Chas. Engelhard, Inc. New bulletin which describes the Gasalyser, a new portable instrument for gas analysis, in addition to gas analysis temperature measurements can be made with the same instrument. Bulletin A-14.

Thermit Welding—Metal & Thermit Corp. A book describing their Thermit welding process in detail. Bulletin S-64.

Scale Prevention—Dearborn Chemical Co. Booklet describing latest scientific methods of treating water for prevention of scale, corrosion and foaming in steam boilers, dealing with related problems in connection with scale and corrosion in other power plant equipment. Bulletin O-36.

Heat and Corrosion Resistant Alloys—General Alloys Co. A new bulletin is available on chrome-nickel and straight chrome heat and corrosion resisting alloys. Bulletin O-17.

Hy-Ten Alloy Steels—Wheelock, Lovejoy & Co., Inc. "Pertinent Points" folders covering physical properties, heat treatment and applications of all grades of Hy-Ten Special Steels. Bulletin O-22.

High Speed Furnaces—American Electric Furnace Company. A complete description of their new models of "AMERICAN" electric high speed furnaces with patented atmospheric control preventing oxidation. Bulletin N-2.

Conveyor Belt Handbook—Wickwire Spencer Steel Co. A new loose-leaf handbook, describing various types of metal conveyor belts for high and low temperatures. This includes the new heavy duty "Alpha" link belt, "Delta" plate belt and spiral type. Bulletin N-37.

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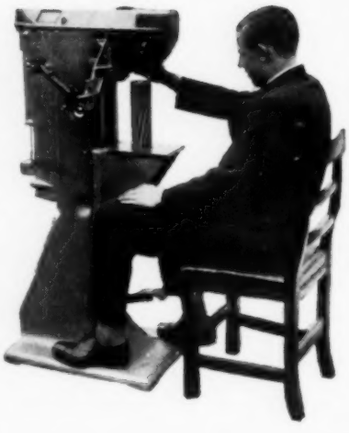

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